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LECTURES

ON

INFLAMMATION:

BEING

THE FIRST COURSE DELIVERED

BEFORE

The College of Physicians of Philadelphia,

UNDER

THE BEQUEST OF DR. MÜTTER.

BY

JOHN H. PACKARD, M.D.,

AUTHOR OF "A MANUAL OF MINOR SURGERY;" TRANSLATOR OF MALGAIGNE'S "TRAITÉ DES FRACTURES;" SECRETARY OF THE COLLEGE OF PHYSICIANS, ETC. ETC.

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TO

SAMUEL D. GROSS, M.D.,

PROFESSOR OF SURGERY IN THE JEFFERSON MEDICAL COLLEGE, ETC. ETC.

Dear Doctor:—

Permit me to dedicate this little volume to you, not less in consideration of your distinguished labors in the study and teaching of Pathology, than in token of thanks for the very kind encouragement you gave me in the preparation and delivery of these Lectures.

Very respectfully yours,

J. H. P.

PREFACE.

By an agreement entered into in 1858, the late Dr. Mütter bequeathed to the College of Physicians of Philadelphia his pathological museum, together with a fund for its preservation, and for the endowment of a lectureship under their direction. The College did me the honor to appoint me to deliver the first three courses of lectures under this bequest; and the volume now placed before the medical public contains the first series of these lectures.

In them I have endeavored to set forth the subject of Inflammation in the light of modern pathology. As a matter of course, within such limits it would be vain to attempt to exhaust a topic of such magnitude and importance; but my aim has been to take up the principal points in regard to it, and to give a plain and succinct exposition of their present aspect. How far this end has been at-

tained, others must judge; my best efforts have been given to the task.

I feel constrained to thank Drs. A. Hewson, T. G. Morton, Edward Rhoads, and Thomas Wistar, of the Pennsylvania Hospital, Drs. C. Morris, and G. H. Humphreys of New York, for their kindness in furnishing specimens, etc. for the illustration of these lectures in their delivery.

J. H. P.

PHILADELPHIA, July, 1865.

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It would scarcely be possible for me, gentlemen, to enter upon the task with which you have honored me, without dwelling briefly upon the circumstances of interest which attach to the occasion.

But one other endowed lectureship of a medical character exists, within my knowledge, in the United States; it was founded by Dr. Shattuck, of Boston, and is on the important subject of Pathological Anatomy. The value of such establishments has however been amply proved by their results to science in the old world; and it is to be hoped that as our country advances in age and prosperity, these and all other means for the encouragement and promotion of learning may be more and more appreciated, and bear ever-increasing fruits.

As most of you are aware, the arrangement under which this endowment was effected was one of the last matters of business which engaged the attention

of our late distinguished fellow-member. It was perhaps the very last strictly professional act which he performed; and fitly closed his brilliant and successful career as a practitioner and professor of surgery. But it is not my duty now to eulogize Dr. Mütter, nor is it indeed necessary. His personal character and influence are still fresh in the memory of many, if not of most of those now present; and his name will long live in the annals of American surgery. His efforts and reputation as a teacher did much to maintain Philadelphia in her ancient place as the centre of medical education on this side of the Atlantic; and the lectureship which now goes into operation, grafted upon the oldest association of American physicians, is added to the other opportunities which this city has to offer to students of the art and science of healing. It is earnestly to be hoped, and may reasonably be expected, that the work begun under such auspices may be productive of important and permanent results.

Before entering upon the actual duties of my lectureship, I cannot forbear congratulating the Fellows of the College of Physicians upon the successful completion of their arduous share in the agreement made with Dr. Mütter. Energy and forethought in no small degree have been needed to carry on, in the disturbed state of affairs for the last four years, an enterprise so costly as the erection of this substantial building; which, so long as it stands, will be a monument of zeal for the interests of the profession, and for the promotion of a science whose followers are eminently free from the greed of personal advantage.

The subject of the present course of lectures will be that of Inflammation. It has been so frequently and so copiously discussed by many of the most eminent thinkers and writers on medical science, that I cannot but approach it with diffidence. But I believe it will be generally conceded that there is as yet no satisfactory theory in regard to this form of disease, and that much of what has been written upon it is vague and inaccurate. And in view of the acknowledged importance of this condition in its relation to other pathological processes, there can be no danger of wasting the time given to its study.

Let me therefore invite your attention to a careful review of the available facts in regard to this morbid state. Many of these facts are so simple and familiar as scarcely to need mention, except in order to the inferences they may support; but others of them are complex not only in themselves but in their mutual relations, and demand earnest and thorough scrutiny. If we would avoid falling into the same errors which have beset our predecessors, the investigation of this mass of facts must be carried on, not with the object of establishing any preconceived theory, but with an unbiased readiness to follow wherever it may lead us. I make this remark, although it may seem a mere truism, because it has special reference to the cause of much of the doubt and obscurity which have encumbered the subject we are now about to approach.

For two reasons it will be unnecessary for me to go into the discussion at any length of the history of opinion on this subject. In the first place, the dif-

ferent views which have from time to time been put forth will naturally come up for comment in connection with the points upon which they bear; and, in the second place, those of them which merit any degree of prominence are, in a general way, familiar to all who have looked into works on pathology.

As already remarked, the subject of inflammation has been frequently and copiously discussed, and that by writers of no mean authority; and yet its special literature is but scanty. It would, indeed, be by no means a tedious or a difficult task to give a list of those who have contributed original material to it. For, although many if not all writers upon general pathology have adopted opinions on this subject, and even defended them with warmth, there has been too prevalent a tendency to the discussion of existing theories, rather than to the more laborious study of facts. Some even among those whose writings have carried weight, would seem to have thought their task was to select from the views already advanced those to which they could give in their adhesion, and not to work out the problem for themselves.

More intimately connected than any other morbid state with the healthy processes of life, inflammation has become better understood as the science of physiology has been developed during the present century. In regard to all forms of disease, but especially I think to this, it may be said that phenomena which once stood out as anomalies or impenetrable enigmas are assuming their true places under definite laws. Or, to speak more correctly, the laws governing both healthy and morbid processes are

coming to light. They have been in force ever since order was brought out of chaos, but the development of them to human perception is yet in progress.

This term development has a peculiar force in its application to natural science. Man's province is not the building up of a system to which nature shall conform, but the humbler one of tracing out step by step the plan originally laid down by Creative Wisdom. Reason tells us that such a plan exists. We establish special or elementary facts, until their concurrence suggests a law. Successive laws are thus developed or laid bare, until a system, or something like it, begins to appear. Possibly the whole wondrous framework may at some future day be revealed. Possibly, although upon this it would be idle to speculate, the entire series may at last blend into one grand fundamental principle.

And here it may be properly remarked, that whatever of obscurity there may be in the processes of nature is due to man's imperfection. There are no conflicting facts, no defective links; all is harmony and order. Cause and effect, in constant and legitimate succession, have been, are, and to the end of time will be, invariably bound together. Hence may be derived the best argument for earnest and untiring research. So far as man can go, his industry must carry him, in following out the clues which facts afford. Nothing can be more opposed to all that we know of nature, than the idea that there is any capricious or inconsequent variation in her operations. And even when we pass from the material world into the domain of psychology, we still find

inexorable law governing all mental processes. Not a single phenomenon comes to pass spontaneously; such a thing is as impossible as that a fully developed living being should come out of nothing.

In studying inflammation, or in fact any disease, the idea is too apt to obtain that something is superadded to the normal economy. But every lesion which occurs is in its causes, phenomena, and consequences as directly and completely amenable to the general laws of nature and to the special laws of life as are the healthy functions of the body. Disease is the condition into which, under abnormal circumstances, the living being passes. It must invariably be due to one or the other, or to both, of two causes,—inherent tendencies impressed upon the organism at the very moment of its entrance into life, or some force acting from without. Besides the mere succession of one action upon another, there is a prescribed order of things, a programme according to which there shall take place certain changes, such as growth, development of organs, degeneration, decay, and death. To each being, it may safely be asserted, there is such a special programme, as to each class or order there is a general one.

Hence a normal ovum, duly fecundated, and placed under wholly favorable circumstances, would of necessity undergo its regular developmental changes into the perfect, mature organism. And, having completed its assigned period of vigorous life, such a being would pass into a state of natural decay, and finally become effete, or in other words die, or resolve itself again into its inorganic elements.

Now there may be either in the ovum or in the fe-

cundating material, or in both, deficiencies which shall make themselves manifest in the course of the development of the animal. Thus may occur various monstrosities; certain parts, such as the head, an arm, a kidney, being absent. The germ may be wanting in the rudiments of muscular fibre in portions of the future frame; or some of the elements of bony structure may be omitted.

This deficiency may go so far that only a small modicum of the new being is ever formed. Cases have not unfrequently occurred in which a mass of hair and one or two teeth have constituted the only developed parts of what should have been a human fœtus.

Redundancy of parts or of tissue-elements is apt to give rise rather to deformity than to disease, as in the case of supernumerary fingers, toes, or mammary glands.

But in the programme before supposed, there may be, perhaps, in the case of any individual, a provision inserted for the occurrence of a certain morbid condition at a certain time; so that there is inherent in the ovum a tendency to the development, it may be at some far remote stage of its life, of cancer, syphilis, or tubercle. Some of the cutaneous diseases, such as eczema, may also be thus inherited. With the nature and mode of this transmission we have now no concern, interesting as are the topics suggested by its mention.

The only other way in which disease can originate in the economy is by the influence of external causes. Mechanical, chemical, electrical, or other conditions definable by physics may thus disturb the organism

or some one or more of its parts. And there is still another set of agencies for which the best term within my knowledge is "vital." They can only affect living beings, and seem to deal altogether with the special manifestation of force constituting life.

Apparent exceptions to this statement may be found, as for example in malignant growths, and in contagious diseases. Here it would seem as if there were actually an engrafting upon the system of parasitic beings. But in the former case it may easily be shown that the new formations are but the outcroppings of tendencies inherent in the germ. They are not foreign bodies, but as it were organs, in which the very same laws of life are in full force, as in the production and maintenance of any other organized tissue. In the latter case, it is the subtle influence by which the disease is communicated which lies beyond human ken. So far as the phenomena go, small-pox is as easily understood as carbuncle. In both cases the mode in which a particular morbid action is set up at a particular spot is for us a mystery.

The superaddition of something to the normal economy, or to any part of it, may induce inflammation, as in the well-known instance of poisoning by certain plants, but here in fact the organism, or a part of it, merely responds to a certain stimulus, by changing its state.

Now it is, perhaps, scarcely necessary to go into an argument to show that inflammation cannot be inherent in a germ; that it cannot be due either to deficiencies or redundancies in parts, except as a secondary consequence; or arise as the result of a

tendeney in the new being, as syphilis, eaneer, or tubercle so often do. It must be excited directly by the influence of some agency outside of the part affeeted. It is the response to an applied stimulus or irritation.

Being so exeited, inflammation may constitute the sum and substance of the abnormal process. Or it may be that the eause of it, such as the poisoning of the system by small-pox, or of the urethra by gonorrhœal contagion, is the main disease, to which the minor and seeondary state of inflammation is more or less exactly proportioned in its extent and severity. Or, again, an inflammatory state may itself give rise to disorders which present special symptoms and entail speeial disturbanees; of this we have examples in cirrhosis of the liver, or in gangrene of a limb from arteritis.

Hence it may be said that the relation of inflammation to other diseases is very analogous to that which, in grammar, the verb "to be" bears to other verbs. It is sometimes met with by itself; sometimes as the principal condition, to which others are auxiliary; and sometimes, perhaps oftenest, as itself the minor and subordinate element of the chain.

Few, if any, of those groups or suceessions of symptoms to which we give the name of diseases are wholly unconnected with inflammation, either as an essential or even prominent and eonstant lesion, or as an almost inevitable consequenee. And here we touch a very diffieult topic, so far as strictly medical disorders are eoneerned; most surgical affections are in this respeet of readier explanation. For instanee,

the rationale of the bronchitis and the inflammation of Peyer's patches, so constantly met with in typhoid or enteric fever, has never yet been cleared up; that of the inflamed state of the tissues in the neighborhood of a cancerous tumor, or a broken bone, is comparatively easy to be understood. In other words, the cause and its effect are in surgical diseases apt to be in closer apposition. How far an actual analysis of the process can be carried, remains to be seen; I shall attempt such an analysis presently.

There is no difficulty in conceiving of grave disease, such as cancer or tubercle, running its whole course, even to the destruction of life, without any high degree at least of inflammation being set up. Why this is not apt to be the case will appear as we proceed. But it very often happens that secondary malignant disease takes place, as in the lymphatic glands of the axilla in mammary cancer, without inflammation from first to last; showing clearly that the latter state is not inseparable from the former.

But there are some diseases, such as small-pox, or vaccinia, in which inflammation is an inseparable constituent. It arises from the localization of a general poison, and passes off when this poison ceases to act as an irritant. I say as an irritant, for every one knows the permanence of the subtle effect of the diseases mentioned upon the system. The mere admission of this statement is enough for my present purpose.

As to the modes in which inflammation is brought about, I shall have occasion to speak more appropriately hereafter, when the subject of its relation to other diseases will also again come up.

This expression "other diseases" implies that inflammation is itself a morbid state. Now there are conditions of the body, or of parts of it, which are according to circumstances healthy or otherwise; and the expressions often used by medical writers would denote that it might be so with the one we are now considering. But I take the position that inflammation is always, wherever met with, a disease; and that the term "healthy inflammation," and all the theoretical views dependent upon it, are incorrect.

I say all the theoretical views, because, as is well known, we sometimes in practice seek to bring on a certain degree of inflammation in a part. But, in so doing, we aim at the incidental benefits which experience teaches us will be obtained. In morals we are forbidden to "do evil that good may come;" but not in physics. The only way known to us of inducing the formation of lymph is to excite inflammation; and we risk this, as in cases of ununited fracture, in order to attain the desired bond between the broken parts. An inflammation of the skin is less dangerous than that of the lung or brain; and we excite the former in pneumonia, or encephalitis, just as a man leaps from the window of a burning house rather than perish in the flames. Of the two evils, we prefer the less to the greater.

The currency which the term "healthy inflammation" has derived from frequent use, in medical writings as well as speech, makes it necessary to defend the position now taken.

If we imagine a living being passing through all its appointed stages, from birth to death, in absolute

health, the idea of inflammation is altogether excluded. It does not, so to speak, enter into the programme at all. Not one of the normal actions of the organism either requires it or gives rise to it.

On the other hand, a part in a state of inflammation is manifestly unsound. Even the unprofessional observer recognizes the undue redness and heat, the swelling, the pain, and the disordered function. Science goes further, and proves that in proportion to the degree of the morbid action the part is rendered more unfit for its regular duty, less tenacious of life, and less capable of returning to its healthy state.

Since, therefore, inflammation finds no place among the processes of health, but its briefest and most general description is a catalogue of abnormal phenomena, we may assume with confidence that it is a disease. And unless there can be such a thing as a healthy or wholesome disease, there can be no such thing as healthy inflammation.

Another position which I would take in regard to this disease of inflammation, and one which seems to me important as simplifying its study, is that it is always and everywhere one and the same thing. Hunter, the pioneer in this field, treats separately of œdematous, erysipelatous, carbunculous, and sphacelous inflammations; and again of the adhesive, ulcerative, and suppurative. And these terms, which have been more or less employed by all who have followed him until within a very few years, have a certain degree of descriptive value. They have, however, found no place in the writings of either Paget or Virchow — the two authors who

must be acknowledged as the representative pathologists of our day. Hunter was the exponent of the reaction against the spirit of pure theory, which had led his predecessors into so many crudities and mistakes. He set the example of diligent observation and forcible description,—perhaps it is not too much to say that he gave a new basis to medical science; and it was natural that a redundancy of terms should be used to indicate groups of phenomena whose mutual relations were as yet unknown.

Recurring then to the statement before made, that inflammation is the response of a living tissue to a stimulus or irritation applied to it, I would insist upon the view that the essential elements of this process are in all cases the same; that the variations in proportionate prominence and severity, which they present in different cases, depend upon circumstances,—the seat of the disease, the state of the system or of the affected part, the character and intensity of the cause, and some external conditions not yet clearly defined.

I have thought it best thus to put this view in a definite and formal shape, although it will again appear in the course of the discussion of the phenomena and causes of the inflammatory process. Œdema, adhesion, suppuration, gangrene,—all these are incidental to or consequent upon the disease which we have to study; they cannot without error be said to bear any other relation to it.

Inflammation is a morbid change in the nutrition of the affected tissue or organ. All its phenomena are either modifications of those which go to make up the process of nutrition, or results of such modi-

fications. This statement has been made by so many authors, and will moreover be so constantly shown to be correct as we proceed in our inquiries, that it needs only to be put forth here in order to introduce a brief survey of the conditions of normal life.

To sum up then the preliminary positions taken with regard to inflammation. It is always the direct and legitimate result of some local cause. It is always and without exception a disease. It is always essentially the same. It is a morbid change affecting the nutrition of the part in which it is seated.

Upon the simplest view, there are three essential elements in the compound idea expressed by the word nutrition. There must be a living organism to be nourished. There must be the material needed for this purpose. There must be some means for keeping up the supply of this material.

In any case, granted these three conditions, the process of nutrition will go on. And it will be healthy just in proportion to the health of the living substance, the appropriateness of the material furnished, and the adaptation of the means provided for its supply in just the due amount.

Allusion has already been made to the existence of a certain programme, according to which the life actions of every organism and group of organisms are arranged to be carried out. Corresponding to this there is a type to which every organism is ordained to conform. From the simplest monad up to the most complex animal, the pre-existence in every case of a certain scheme may be asserted. And as might *a priori* have been supposed, the plan

of each organism and the arrangement of its processes are exactly proportioned in complexity.

In the human body, with which alone we need now concern ourselves, we find therefore a web of conditions, which to the uninitiated might seem hopelessly tangled. It may, however, be reduced to simpler terms without any great difficulty, by approaching it in the right way.

Leaving out of the question for the present, then, all other considerations, and looking only to the expression of the essentials of nutrition, we see the tissues, the circulating blood, and the vascular system as a whole. In the ovum, at its first stage of development, the new being lies in contact with its food. As it becomes separated from this, the permanent provisions for its supply go into effect.

The process by which the tissues of the embryo drew upon the vitellus, or yolk, for their own nourishment and for the formation of fresh elements, commonly called assimilation, is the same as that by which they derive like supplies for a like purpose from the blood as it flows by them.

It must not be forgotten that the blood is as truly a living mass as is the tissue; and between these, at once separating and connecting them, are the living walls of the vessels. As the new being assumes its shape and proportions, its vessels and the contained blood are simultaneously developed, and both are in exact ratio in quantity and quality to the rest of the organism. The first moment of existence of a heart and aorta is the first moment of their pulsation, and that pulsation propels the tiny blood-mass, itself just called into life, through every part of the little crea-

ture. Tissues and blood begin their interchange on an infinitesimal scale, but with all the perfection of plan which shall mark the full-grown being. From this time forward, provided there exists the needful supply of material from without, the marvelous process never ceases until its appointed time of life is fulfilled.

It is the power of keeping up this interchange, of undergoing continual waste and as continual repair, of retaining form in spite of and at the same time by means of the incessant loss of molecules and substitution of new ones for those lost, that constitutes vital force. No sooner does this mutual relation between the blood and any cell cease, than the active life of that cell ceases also. No sooner is there a change in the relation, outside of certain bounds, than the health of the cell is impaired. And the same is true of fifty or a thousand cells as of one. If in the liver the cells of a certain portion and the blood passing through that portion come to assume such a relation that their interchange of chemical elements cannot take place normally, a state of disease is initiated in that part.

Now I assume that upon the chemical elements aggregated together into the shape of a living being, at any stage of its existence, a certain power is bestowed. And I use the word "living being" to denote the cell, the typical form of life. The chemical atoms which constitute a cell hold this power in their corporate character. It is the power of living, or, to use the common phrase, Vital Force. This term seems to me to set forth best the exact property meant—an inherent capacity to perform the func-

tions which go to make up life. Further explanation of it seems to me impossible. We merely see that the power and the form of life are inseparable. The form is the visible sign of the power, and vanishes when this becomes extinct.

It makes no difference whether this vital force be regarded as a mere modification of other physical forces,—of heat, of electricity, of chemical affinity, —or as a special endowment from the Creator to each separate creature. In this manifestation, it stands alone; man can do away with it, but he cannot confer it.

Between the living tissues and the living blood there is an incessant interchange, the blood yielding up its supplies of nutritive material, the tissues using it and returning what they do not want. But besides this relation between the tissues and the blood, the former are endowed with functions,—it may be to give mechanical support, to move one organ upon another, to secrete, to carry off and eject noxious substances, to feel. Every such action, however trifling, involves a change in so much of the tissue as takes part in it. Obviously, in a perfect organism, the structures composing it will be exactly adapted each to its own duty—each will have blood enough furnished to keep it not only merely alive, but in a state to do the work required of it.

This, however, does not constitute all of nutrition in the higher animals. Wherever a nervous system exists, it has an important influence upon the process in question. Beginning apparently on

an equality with the liver, or any other organ in the embryo, it gradually gains in rank with advancing life, until it comes to be a sort of governor and regulator of all the rest. Abundant evidence exists to show the absolute necessity of its aid to the maintenance of due nutrition in the other organs. Mr. Paget, in his admirable work on Surgical Pathology, adduces numerous cases showing the immediate effect exercised by the division or severe injury of a nerve upon the nutrition of the parts to which it is supplied. But the latest testimony on this point is given by Drs. Mitchell, Morehouse, and Keen, in their interesting essay on Gunshot Wounds of Nerves. These writers say:—

"One of the most remarkable of the nutritive changes induced by nerve injuries, is wasting or atrophy of the muscles supplied by such nerves. It may exist alone or be associated with like conditions of the skin and its appendages.

"Atrophy of the muscles of an entire member is sure to follow complete division of its nerves when there is no subsequent repair. In this case the muscles waste alike, the areolar tissue shrinks, the vessels fade from view, and the pulse becomes feeble and small. The rate at which this process goes on varies greatly, but it begins very early in extreme cases, and continues until nothing is left but bone and degenerated areolar structures, covered with skin whose altered surface tells of the singular blight which has fallen upon the member.

"So complete a destruction is commonly the work of years; but where, as we have seen in certain nerve wounds, the main artery has been also destroyed or interrupted, the atrophy which followed was, as may be supposed, unusually rapid." (p. 69.)

These authors incline to the belief that there are nutrient as well as sensory and motor nerve fibres.

Their remarks on this head are so important that I cannot but quote them:—

"Let us now add to these facts, that a nerve may be hurt and partial paralysis occur without atrophy, and that the atrophies bear no strict relation to the extent of the paralysis, and we shall have acquired sufficient evidence to show that there are in muscles motor nerve-fibres and nutrient nerve-fibres, and that the animating centre of these latter lies in the spinal column. On this theory, and on this alone, can we explain all the facts before us.

"Analogy also lends us some support; since, as we shall hereafter point out, it is necessary to admit that in the skin as in the muscles there are nerves of special function and nerves presiding over its nutrition. In fact, the proposition which we have thus stated is well sustained by the views of many modern physiologists, and will but be strengthened by these added proofs.

"When, therefore, a nerve is injured, the muscles may be paralyzed, sensation destroyed, or nutrition attacked. But for obvious reasons these triple results will usually occur in one and the same case, but in differing degrees,—as motor, sensory, or nutrient nerve-fibres happen to suffer more or less." (p. 75.)

They further say of these nutrient nerves:—

"Whether they are sympathetic fibres, as we believe them to be, and whether they produce effects directly on the tissues, or only through their control over the vessels, are points which our cases do not aid us to clear up, and for these reasons we decline to discuss them." (p. 76.)

It is not my present purpose to enter at any length into this subject, but I cannot forbear mentioning one or two points in regard to the idea that the nutrient nerve-fibres are appendages rather of the spinal cord and great sympathetic than of the brain.

Nutrition may be carried on to perfection without any brain at all, as in the anencephalus monsters

sometimes born at full term. Here the spinal cord and the sympathetic system are fully developed, and from one or both of them must be derived whatever nerve-force the other parts of the fœtus have needed for the carrying on of their nourishment. It may, indeed, be argued that the nervous system is itself, in intra-uterine life, nothing more than a growing mass, like the liver or lungs, and has not yet acquired its functions; but the frequent and forcible motions of the child within the womb, as well as the fact that all the other organs, except the lungs, do exercise their functions in some degree before birth, would militate strongly against such a view.

Again, the result of Mr. Paget's observations has been, that in cases where "defective nutrition follows injury of the spinal cord, it appears to be directly due to the injury of the sensitive, rather than the motor, nerve-fibres."* But the same author remarks, after mentioning several cases:—

> "None of these cases, however, enable us to say whether the influence on nutrition is exercised through sensitive fibres of the cranio-spinal system, or through sympathetic fibres; nor do I think this question can be yet determined."

We may therefore adopt it as our creed in regard to nutrition, that the healthy tissues, being kept in relation with blood containing what they need to supply their own waste and to carry on their functions, will, under a certain established but not yet understood influence from the nervous system, maintain themselves and play their part in the economy

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* Lectures on Surgical Pathology, p. 55.

by means of what they derive from the blood as it passes them.

And here two points seem to call for further notice:—

One is the inseparable connection between nutrition and function. A well-nourished part never fails to perform its function, which indeed is the test and evidence of its being so nourished. For, be it borne in mind, the conditions laid down as those of healthy nutrition had to do with both parties to the compact, if we may so speak. Healthy hepatic cells cannot help taking from the blood coming to them through the portal vein the ingredients of bile, if that blood is properly constituted; nor can they help taking from the healthy blood in the hepatic artery the materials to supply the waste incident to their function, provided in each case that the due nervous influence is exercised upon them.

Hence function and nutrition may be said to stand in a relation of mutual dependence.

The other point which I would here urge is, the great importance of a thorough realization of the cell-doctrine and its bearings, in all physiological and pathological inquiries. The bare fact that all organized beings are made up of aggregations of cells may be admitted, but more than this is needed to give it its full value in practical research. And I think the merit of having developed the capacities of this theory belongs to Virchow, who must indeed be looked upon as the leading pathologist of the present time.

The expression before used, that the cells were in relation with the blood flowing past or among them,

is sufficiently accurate for general purposes, but not for that now in view. For in every tissue in the body, so far from each cell lying directly in contact with a vessel, the great majority of the cells lie either in close apposition to one another, or embedded in intercellular substance, the interspaces of the vascular meshes being filled up with them, thus disposed in cumuli. Thus it may be that some cells have five, some ten, some fifty or more others interposed between them and the nearest blood-current. Nay, some tissues, such as articular cartilage, are wholly destitute of vessels.

Hence the process, by which the nutrient material contained in the blood finds its way to all the tissue elements which need it, must be further explained—and this explanation will be found to have an important bearing upon some points to be hereafter discussed in the pathology of inflammation.

The mass of blood, which, by any one contraction of the left ventricle is driven into the aorta, and thence to the body at large, is divided up as it comes successively to the arteries of smaller and smaller size, until at length it is distributed among an infinite number of exceedingly minute arborescent systems. Here the arterial or elastic character of its containing vessels is lost, and the network of capillary tubes begins, by which the ultimate relation between the blood and the tissues is effected. For the sake of completeness it may be added, that this system of capillary vessels resolves itself again on the other side, if we may so speak, into the venous system, the minute tubes of which, formed by the junction of capillaries, run together, and the larger

vessels so formed again join to form still larger, until the blood, gathered up in this way again after its function among the tissue-elements has been accomplished, returns to the heart, to be again sent to the lungs for aeration.

During this process of circulation, as perhaps need hardly be said, the various organs abstract from the flowing blood that which they need for their nutrition, and those of them whose business it is take also the matters to be secreted for further use in the economy, as well as such as are to be excreted or carried off altogether. Moreover, various effete substances are cast back into the blood by the tissue-elements, to be carried to the appointed places for their ejection or renewal. It is in the capillary portion of the vascular system that these changes in the blood take place; it is therefore of course in the tissues corresponding to this that the complemental changes are effected.

Now the point toward which these statements, familiar as they must be to many of those who now hear them, should lead, is that the relation thus established is between the blood in the vessels and every single cell or tissue-element of the mass to which those vessels are distributed. There is no vagueness; the cell between which and the nearest capillary tube fifty other cells intervene, has its share of the nutrient material to get, its effete particles to throw off, its infinitesimal share to perform in the work assigned to the organ of which it is a part, as well as any one of the other fifty. And this is just as true of a sluggish and lowly organized tissue, such as that of bone, as it is of an active and

highly developed one, such as that of the brain or the liver.

Unless this fact is realized and borne in mind, the cell-theory becomes, for all practical purposes, nothing more than a dead letter. It is the secret of all tissue changes.

It would be very interesting to study here the subject of the production of animal heat; which, indeed, is closely interwoven with that which has now engaged us; but I shall have occasion to bring it up again in a connection still more appropriate, when the abnormal heat of inflammation has to be investigated. I therefore waive it for the present.

Of course the character and extent of the interchanges between the blood and the tissue-elements will be determined by the strength of the special affinities existing between these two factors. So long as a cell needs what the blood in its neighborhood contains, and can attract it with more power than that by which it is held; and so long as certain chemical substances, effete as regards the tissue-elements, are either attracted by the blood, or are expelled from the tissue-elements and find a place in the blood by sufferance, as it were, the interchange must go on. So long as the function of a cell is discharged, so long it wastes away, and must either dwindle and die or be repaired by a fresh access of material; which is equivalent to saying that so long as the tissue is active, it continually needs new material in proportion to its activity, that it may fulfil the law of life—change of material with retention of form. And nature provides for the incessant supply of this ever-recurring want, in the arrangement of

the blood-vessel system in such a close and intimate relation with the tissues. If in any way this affinity is lessened, increased, destroyed, or altered, in just such a mode and degree will the mutual relations between the blood and the tissues be affected.

It is a matter of the commonest observation that the different tissues possess very different degrees of activity in the processes by which they manifest their life. And it is equally certain that in the same tissue this degree of activity is different at different times. The former fact is readily explained on the ground that one tissue is intended to discharge an active duty, involving much waste and necessitating much repair, or, in other words, a very rapid substitution of new molecules for the old, while another tissue has assigned to it a function in which there is but little waste, and consequently but little atomic replacement.

And the chemical composition, as well as the organic form with which each part of the living body is endowed, corresponds accurately with the share it is to take in the processes of the economy. All comes to pass according to the scheme of life and the plan for the living organism, with an accuracy infinitely beyond that which we admire in the construction of a locomotive or a palace.

This prearranged plan does not, however, of course, account for those changes in the activity of a tissue which occur from time to time, and which, although oftentimes great and sudden, are still within the bounds of health. Such changes are invariably due to some agency external to the tissue in which they occur. For the power of spontane-

ous action does not exist in any molecule, atom, cell, tissue, or organ of the body. The property of life is held by the material elements of the body in their corporate character, (to repeat an expression before used,) and confers upon them individually no more power of independent action than steam acquires by being made the servant of man. The only difference between these two cases lies in the fact that the servants of the organism are banded together in squads, to each of which is given a livery, and each of which blindly obeys all influences which affect it. This principle of blind obedience to the direct operation of external forces pervades all the material part of created nature; it is only in the domain of mind or its analogue instinct that anything like voluntary resistance is to be observed. Hence it is not possible for a cell or a congeries of cells to elect that they will take up more or less nutrient material; that they will perform their function quicker or more slowly; or that they will alter the quality or character of the matters separated by them from the blood.

Nor does the regulating power reside either in the organs of circulation or in the blood-mass. It is true that not only is a certain degree of force and rapidity of the heart's action necessary to the due nutrition of the body, but a more or less exact ratio exists between these two things; and, moreover, certain organs or tissues are more sensitive to changes in the amount of nutrient material supplied them in a given time than others are. But this does not involve any power such as that we are now considering.

And if the heart does not possess such a power, it does not surely seem that the arteries can. We can no more assume that the hepatic artery, or the gastric, can resolve at any time to transmit more or less blood, than we can that the femoral or the dorsal artery of the foot can do so.

The same argument applies to the capillary vessels. They have no function except to allow the current of blood to flow along them—no contractile power except their elasticity, and no active dilatation. Of all the distinguishable parts of the body, these are the most entirely passive, as to their own state at any time. How, then, can they be imagined to govern the changes in condition of other organs?

It is perhaps but right to mention here that the views just expressed are at variance with those of most authors, physiological as well as pathological. The idea which has found general favor is, that the small vessels have a capacity of contraction and expansion under stimulation, so as to admit more or less blood into the part, and thus influence its practical activity. But to imagine this to be the case seems to me to be to ascribe to the vessels an independent power, an arrogance of control, as it were, not warranted by their anatomical position; and to ignore the special tissue-elements, which are both structurally and in function far more important.

These points will, however, necessarily come up again, when they can be discussed to better advantage, in connection with the phenomena of inflammation; they need not therefore detain us now.

The blood-mass itself may be regarded as a passive member of the economy. It is endowed with

certain affinities, by virtue of which it attracts to itself substances already existing in the tissues among which it flows, and in like manner gives up to those tissues some of its components, either essential or accidental. It may of course, as so often in therapeutics, be made the channel by which the functions of certain organs are influenced, simply by adding to it substances which have chemical affinities with the tissue-elements. Still, it is clear that the blood-mass cannot itself spontaneously induce any change in the nutrition either of the whole body or of any of its parts.

Where then is the source of these changes in nutrition to be sought? The answer to this question can hardly be given in anything like simple terms.

In the first place, then, we have various changes in the surroundings of the animal organism.— Changes in the chemical composition, in the temperature, in the electrical state of the atmosphere. Changes in the nature and quantity of the matters introduced into the economy in the way of food and drink. Changes in the mechanical relations of parts to one another as well as to external things.

Again, we find changes in the nervous system, and in the mind, of which it is the direct exponent. How these changes arise cannot always, or perhaps often, be explained; how they are made operative upon other parts of the economy, we have yet to discover. But we know that a certain degree of analogy obtains between electrical phenomena and those of the nervous system; and to this we cling in all our study of the latter.

It is, however, by the exercise of function, or per-

haps more correctly as the effect of the normal stimuli which should induce this, that nutrition undergoes the most marked changes within the bounds of health. For in this manner, always supposing an adequate supply of nourishment to be ready to make good the waste involved, the action of the part is quickened, and by virtue of its excitability the reparative process goes somewhat beyond the exact measure of the loss. Should the demand for the exercise of function be excessive, the loss will be in proportion, and the part will be unable to avail itself of the means of repair. The terms I have used in making these statements may perhaps be open to some technical criticism; but they are accurate enough to answer the present purpose.

When this stimulation of a part occurs, the first noticeable effect is an increase in the amount of blood flowing through its vessels. The skin becomes flushed, and feels fuller than before, when its action is thus quickened. A muscle which has been exercised is harder, larger, and more tense than it was before—and experiments have shown that its temperature rises.

Now, there is one condition present in such a case which we cannot ignore, and yet of which it is very difficult to estimate correctly the prominence in the whole process. It is the reflex influence of the nerves of the part. When the stimulus is applied, there is, as it were, a report made to the central portions of the nervous system, and a response made to this, through the afferent and efferent nerve-fibres respectively. This may be either with or without the cognizance of the brain—with or without sensa-

tion. The difficulty then lies in estimating the proportion in which the response to the stimulus is due simply to the tissue itself, or to the influence of the nervous system, thus secondarily derived.

To sum up then the ideas which I have endeavored to maintain in regard to healthy nutrition. It is a process which takes place between every separate cell and the blood with which it is in relation. Healthy cells or tissue elements, a due supply of suitable blood to them, and a certain influence of the nervous system, are the requisites. Nutrition and function go together, and are mutually dependent. Changes in the nutrition of any cell can only be brought about by some influence outside of that cell; and this may act either directly upon the cell, or through the nervous system, or in both ways.

LECTURE II.

COMPARISON BETWEEN ORGANIZATION OF THE LIVING BODY AND THAT OF AN ARMY — PHENOMENA OF INFLAMMATION — DIAGNOSIS — REDNESS; ITS MAIN CAUSE AN INCREASED FLOW OF BLOOD TO THE PART, DUE NOT TO RELAXATION OR ACTIVITY OF THE VESSELS, BUT TO THE VIS A FRONTE EXERTED BY THE CELL-ELEMENTS — HEAT; DEGREE OF; CAUSE OF, CHIEFLY COMBUSTION; VIEWS OF CARPENTER, DRAPER, DALTON, AND MILNE-EDWARDS ON THIS SUBJECT.

In my lecture of last week, gentlemen, after speaking of the general causes of disease in the economy, and their division into the inherent and the extrinsic, I laid down certain propositions in regard to inflammation, the chief of which were: that it was always due to external influences—that it was always and everywhere a state of disease—that it was always one and the same thing—and that it consisted essentially in a change of nutrition. From this latter proposition I was led into a discussion of the normal phenomena of nutrition, and of its variations within the bounds of health. My great object was to show the importance of the cells or tissue-elements in the carrying on of all the processes of life, and in the changes to which they are subject,—in opposition to the views which have at times gained even greater currency than at present, and according to which the controlling power would lie somewhere in the vascular or in the nervous system. This importance of the cells

is theoretically admitted perhaps by every one, but it has not had that influence in either physiological or pathological reasoning to which it seems to me to be entitled.

Before proceeding to the discussion of my main subject, I would further illustrate the general process of nutrition, by means of a comparison which I trust will not seem a forced or a fanciful one.

Let me then draw a parallel between the living body and an army. In both these organizations, individuals are massed together for the accomplishment of common objects; in one sense they cease to act as individuals, while in another they continue to do so. They are massed for the purpose of nutrition and the performance of function; they keep their separate form and shape in order that each may take his due share, no more and no less, in the distribution of supplies and the assignment of duties.

The men of an army are massed into companies, regiments, brigades, divisions, and corps. They are uniformed, armed, and equipped. Every officer and man has his prescribed duty, permanent or changeable; and upon the efficiency with which this is discharged by each one depends that of the whole. There may be some original defect in the material or in the organization of the army, or of any portion of it, which shall wholly or partially cripple its operations, or which may break it up altogether.

The general commanding controls, through his subordinate officers, every individual man in his force. He disposes his cavalry, infantry, and artil-

lery so as to carry out the plan of his campaign or siege. Under him, the quartermaster's and the commissary's departments provide for the supply of what is needed for the transportation, quartering, and subsistence of the troops. The paymaster's and the medical departments are also duly arranged.

If now any corps, division, regiment, or company of this army is captured, cut up, discharged, demoralized, or in any way rendered useless, or injurious to the rest, the fact will influence the remainder to an extent and degree corresponding with that of the disaster. If the officers are inefficient, or there is a want of energy or judgment in the quartermaster's or the commissary's department, the trouble arising will be more or less serious according to the degree of the defect and its nearness to the central point of the organization. If any portion of the army is overtasked, or composed of bad material, the operations of the whole will be interfered with just so far as they depend on the share to be taken by the troops concerned. Should the necessary supplies be out of reach, and the stores on hand exhausted, the men must suffer individually, and their efficiency as a mass will be impaired in an equal degree.

In like manner the nervous system may be said to control and take cognizance of the state and operations of the living body. The digestive and circulatory systems furnish the supplies of nutriment to the whole. And so long as the original constitution is sound, the tissues and organs properly developed, the functions normally exacted of each part, and a due amount of suitable nourish-

ment distributed, the result is and must be absolute health.

But if an injury is sustained from without, or if the nervous system is weak and irritable; if a tissue is originally defective, or a part is overworked; if the supply of nutritive material is insufficient or improper in kind, disturbance will ensue. And from any or all of these causes disease may arise, affecting the whole or a part of the body according to the extent and severity of the primary evil.

Having drawn this comparison, let us now lay it aside, to be referred to from time to time as the points come up for the illustration of which it is meant to serve; and let us proceed to examine first the phenomena, and then the causes, of inflammation.

The phenomena by which inflammation makes itself known are, — redness, heat, swelling, pain, alteration in function, and in most cases effusion of new material. These, more or less modified by circumstances to be presently mentioned, are the evidences of the disease. Suppuration, when it occurs, is invariably the result of inflammation. Ulceration is either preceded by inflammation, and is caused by it, or is attended by it. And when, in examining a body after death, we find adhesions between parts naturally unconnected, as for instance between the costal and pulmonary pleuræ, we know that these are the traces of inflammation.

Hence this morbid state not only gives rise to certain phenomena during its continuance, but induces results of a secondary and non-essential character, some of which are under favorable cir-

cumstances but transient, while others pass into permanent conditions.

Singularly enough, it is only these non-essentials which, when existing by themselves, afford unmistakable evidence of inflammation. For although inflammation may occur without them, they cannot be brought about except as its results. Heat, swelling, redness, alteration of function,—any one of these may be due to causes purely physiological; but neither effusion of lymph, ulceration, or suppuration, ever exist without a previous or attendant inflammation. Pain is often met with where no structural lesion is discoverable.

Instances illustrative of these statements are not far to seek. Heat, swelling, and redness are the well-known phenomena of the erethism of erectile parts, and of the irritation which, although it often borders upon inflammation, and may run into it, is a state quite distinct from it. Alterations of function, in degree and quality, are frequently observed, in the various glands, in the nervous system, in the stomach, without any of the symptoms being present which are known to indicate inflammation of those parts. And the pain of neuralgia, severe and wearing as it often is, neither results from inflammation nor gives rise to it.

It is therefore the conjunction of all these symptoms to which the name of inflammation is properly applied.

But there are cases of this disease in which some of the phenomena usually belonging to it are either absent or masked. Such are those inflammations which occur in parts where mechanical obstacles

exist to the swelling—as for instance under strong fasciæ; or in parts possessed of but little sensitiveness, and in conditions of the constitution which blunt the nervous system to pain, as in the pneumonias of old and imbecile subjects. Alteration in function can scarcely fail to ensue upon inflammation, but may attract little notice, either because, as in the case of the spleen, the normal performance of the function is not directly observable, or because other parts are apparently more involved, as when joints are inflamed, but the difficulty of motion seems to lie in the neighboring tissues.

From what has now been said, it may be justly inferred that it is not always easy to discriminate between the inflammatory state and those conditions which present some of its symptoms; and the practical results of error in diagnosis in such cases have been highly disastrous. I say "have been," because it is much less common for practitioners to fail in making this distinction now than formerly, before the difference had been clearly pointed out; and because moreover, even if the one state should be mistaken for the other, the extreme measures once in vogue have been in great measure discarded, and a less heroic and more philosophical practice adopted.

Nevertheless, in doubtful cases the conditions which may mask the phenomena of inflammation should not be forgotten; and obscure symptoms should be traced carefully up to their real causes. Often the constitutional state of the patient serves to clear up the matter, irritative fever seldom if ever failing to attend inflammations of important

organs or of high grade, although their immediate indications may be ill-defined.

I propose now to take up the phenomena of inflammation one by one, with a view to determining their causes and their significance. Those phenomena are, to repeat once more,—redness, heat, swelling, pain, effusion of lymph, and alteration of function.

The *redness* of inflammation varies greatly, as every one knows, in different cases; and this not only in degree but in form. It is sometimes pink, sometimes crimson, scarlet, or purple—sometimes diffused evenly over the whole surface of the affected part, sometimes shading off gradually from a central focus. In true inflammations it always passes imperceptibly into the healthy color of the neighboring tissue.

The differences named depend partly upon the character and extent of influence of the cause of the disorder, partly upon the anatomical structures concerned. When the disturbing cause acts strongly upon a small area, the redness seems to find its focus here, and to diminish in every direction around it, as when a small foreign body is embedded in the skin. When, as in the case of a superficial burn or scald of some extent, a large area is involved, the whole of this area may be deeply reddened, the toning down into healthy color occupying but a narrow margin around its border.

Again, in some tissues the morbid state tends to spread around its original seat, as is so often seen in the peritoneum and in the conjunctiva. Here,

however, another condition seems to come in; this spreading is much more apt to occur in parts where tactile sensibility is wanting, or very limited in degree.

Inflammations which occur as the result of systemic disease are perhaps much more apt to attack the whole of a structure, as for instance in rheumatic sclerotitis, than are those of local origin—and hence in the former case the redness is much more apt to be evenly diffused.

But in any case, the cause of the coloring in inflammation must be found in the increase in the amount of blood present in the part. And the first element in this increase will be the filling up of the vessels, as may be seen in the web of the frog's foot, irritated while stretched out under the microscope. Vessels which in the normal condition had flowing through them a free and slender stream, will now become distended by a torrent, the impetuous rush of which continues until the channel becomes choked up by the hurrying crowd of corpuscles.

Another element in the rationale of this reddening is to be found in the passage of red corpuscles through vessels which in the normal state of the part were traversed by the liquor sanguinis only.

Still another, but a less important and less easily verified condition, is the breaking down of the red corpuscles, and the escape of their coloring matter, which becomes soaked up by the surrounding parts, so as to stain them. Such a state of disorganization of the blood-mass contained in the vessels of an inflamed part could hardly happen, it would

seem, unless the tissues themselves were ready to break down and lose their vitality.

Assuming then that the quantity of blood in an inflamed part at any given moment is greater than it normally should be, it may naturally be asked whether this is a mere accumulation, or an actual increase in the amount of blood passing through the vessels of the part in a given time? And in answer to this question, an experiment made by Mr. Lawrence, of London, and described by him in his "Lectures on Surgery," is often quoted. A young man whose hand was inflamed was bled in both arms. From the side on which the disease was, ʒxv of blood flowed, while ʒiij were flowing from the sound limb. But although this case has been again and again quoted by different writers, it seems to me that it cannot be received in evidence without qualification. Unless the two wounds corresponded precisely in size and situation,—a most difficult thing to ensure,—and unless the venous system of one arm was exactly like that of the other, and the muscles were in the same state of contraction in each, the comparison could not be made with accuracy. Moreover, the amount of difference stated is so great that it seems in itself to cast a doubt upon the correctness of the observation.

But we do not need to resort to proof of this kind. It is manifest that all around the focus of the inflammation there is an afflux of blood. An incision made into a slightly inflamed part will be followed by a copious hæmorrhage, often with the immediate effect of blanching the surface, and the substance of the tissue so far as it can be observed,

so that it resembles much more closely the healthy structures around. When, however, the grade of the disease is more severe, the bleeding will continue freely for a length of time, only subsiding gradually as the excitement is lessened by the direct abstraction of the food of the part. The difference is one of degree only; more blood obviously flows from a slightly inflamed part than from the healthy tissue, and the difference is greater in proportion to the existing excitement.

Furthermore, in studying this process experimentally in the web of the frog's foot, we can actually watch the increase in the blood-current. We see the thronging corpuscles as they rush along the vessels, reminding one of the hasty gathering of an excited crowd when a disturbance occurs in the streets of a city.

But this fact of the increased amount of blood flowing through an inflamed part is of itself a mere step; the important point is to determine how such an augmentation is brought about. And here we approach a subject which although much debated, still remains unsettled, but which it seems to me admits of as complete explanation as any of the other phenomena of living beings. That is to say, so far as the physical laws and conditions operative in these changes are concerned, they can be traced; but there is a boundary beyond which we cannot go, the Author of life reserving the comprehension of that mystery from us.

The ideas entertained on this subject, even long after the corner-stone of our modern system of physiology was laid in Harvey's great discovery of the

circulation of the blood, were singularly vague and crude. So eminent a man as Boerhaave described the cause of inflammation as twofold: a viscosity of the blood causing it to become obstructed in the small vessels, and the larger globules of the blood passing into channels too small for them. To the latter phenomenon he applied the name of *error loci.* Cullen thought a spasm of the extreme arteries was the starting-point of all the phenomena of inflammation; Hastings and Wilson Philip, on the contrary, argued that the minute vessels became debilitated and relaxed, so as to afford less than their normal degree of resistance to the blood-current, and thus allow a state of hyperæmia to arise.

Hunter, to whose weight of authority allusion has before been made, suggested the idea of an active dilatability of the vessels, by which they expanded so as to admit more blood than in the normal state. And this view of "increased action of the vessels" has been accepted by many of those who have followed him.

All these theories, however, (some of which should rather be called hypotheses,) deal exclusively with one only of the factors in the process of nutrition as we have studied it. It will be remembered that the essential elements necessary to a nutritive process were,—the structure to be nourished, the material needed by it, and a provision for the regular and duly apportioned supply of that material as wanted.

Of these three conditions, it is obvious that the one last named is subordinate to the other two—and in speaking of the process of healthy nutrition

and its variations, I tried to show that these latter could not be ascribed with reason to changes in the vascular system merely. There must be a consensus,—a joint action on the part of the tissues, the blood-mass and the vessels, for the regular carrying on of the normal process, and if either one of the conditions becomes changed, the others must be modified accordingly.

If at any point an increase in the supply of blood is needed or called for, (the tissue-elements being stimulated,) more blood will be drawn thither. And the current in the vessels of the part becoming fuller and stronger, those vessels will give way to the augmented outward pressure they sustain from their contents, and will expand.

Another argument against the adoption of any theory which assigns to the vessels an active part in the causing of the increased flow of blood in inflammation, is that no direct evidence can be derived from experiment in favor of such a view. It would hardly be worth while for me to quote the descriptions given by different authors of the phenomena observed by them in the transparent parts of some of the lower animals, with the aid of the microscope. It is in the nature of things physically impossible to apply to the vessels alone any stimulus; and hence in the experiments made in the artificial induction of inflammation, for the purpose of observing its phenomena, the changes which take place in the vessels cannot be isolated; they must be regarded as only parts of an apparatus. Not only the vessels, but also the nerves and the proper tissue of a frog's foot must experience irritation

when the point of a needle is drawn across the extended web. So also with chemical agents. When a drop of acid, or of a solution of salt, is applied to the web, we cannot suppose that its influence is unfelt by the nerves; nor can we, in view of the constant endosmotic interchanges that are going on between the contents of the capillaries and those of the tissue-cells, ignore the fact that such a chemical agent would be apt to very materially affect the relative densities or the affinities of the substances concerned. An increase of the endosmotic current toward the blood would augment the bulk of that liquid, and an enlargement of the calibre of the vessels, at the expense of the size of the cells whence the flow took place, must ensue. Doubtless this is the true explanation of the fact which occasioned Dr. Thomson so much surprise, that the application of a solution of common salt was followed by dilatation of the vessels. His observation was correct, but he erred in his interpretation of it—or rather, he wanted the previous facts which would have explained it.

And all analogy is against the supposition of an active dilatation of the vessels. Nowhere in the body do we see a muscle lengthening itself, any more than its owner can add a cubit to his stature. Muscular tissue has the property of contracting; every muscle has its maximum length, to which it attains when all contraction ceases in it, but beyond which it cannot go. And in proportion to the diminished exercise of contractile force, short of actual cessation, the muscle relaxes; but no ingenuity can make this into active dilatation.

The so-called yellow fibrous or elastic tissue yields to a stretching force, contracts when this ceases, and by mere elasticity may lengthen, just as an India-rubber spring will do. Mr. Wharton Jones, in a Report on the Theory of Inflammation, published in the British and Foreign Medico-Chirurgical Review, 1844, says:—

"Animal physiology recognises no other motor agent than contractile fibre, *i.e.* a fibre capable, under certain conditions, of becoming shortened in the direction of its length, and that with force, but when no longer under these conditions readily resuming its former length."

Everywhere, to counteract muscle, we have muscle so arranged as to operate in the opposite direction with greater force. The gastrocnemius does not actively dilate when the foot is to be flexed on the leg, but another set of muscles comes into play, and as the former slackens its pull, the latter contract. The sphincters do not spontaneously elongate their fibres in order to the enlarging of the openings they respectively command, but they yield to pressure, and to the more powerful contraction of the longitudinal layers of muscle to which they are opposed.

It surely, therefore, is not philosophical to suppose that capillaries, to all appearance made up of wholly structureless membrane, should have a power which does not belong to muscle, or to any other part of the organism. Nor can we with any more reason suppose that either small or large arteries, by virtue of an elongating power possessed by their circular fibres, can enlarge their calibre.

A theory which has been suggested to me, but which I do not remember to have seen in print, is

that the increased flow of blood to an inflamed part is caused by the more active contraction of the small arteries supplying it, under the influence of the disturbing agency, whatever it may be, which gives rise to the inflammation. But there are several arguments against this view, which indeed does not seem to materially differ from that advanced by Cullen, and before alluded to. In the first place, the muscular fibre entering into the walls of the arteries is of the unstriped or involuntary kind—and the distinguishing feature of this form of tissue, aside from its appearance, is the slowness of its contractions. Like the muscular fibre of the intestinal walls, it shortens itself gradually; and no amount of irritation can induce a rapid alternation of contraction and relaxation, such as takes place in the heart. The throbbing of the arteries of an inflamed part is not due to their own pulsation, but to the successive impulses given to a full stream of blood contained within them.

Again, this arterial contraction, if it takes place, must be either continuous, or intermitting and pulsatile. But if it were the former, it would shut off or lessen the stream of blood, instead of increasing it; if the latter, it would change the steady flow of the current through the capillaries into an oscillatory one. Neither of these changes is, however, noticed; the flow of blood is augmented in force and volume, but does not become pulsatile.

In further proof of this view may be urged the pathological effects noticed as following the use of large quantities of spurred rye; which, as I need not tell many of those who hear me, contains a sub-

stance which acts upon the involuntary muscular fibres so as to cause them to contract. The lessening of calibre of the arteries, due to this agent, by diminishing the supply of blood, induces gangrene of the extremities, not preceded by inflammation or congestion. And it would have to be shown, in order to uphold the theory that the contraction of the arteries is the cause of inflammatory redness, that this contraction was different from that due to the use of ergot. The idea of its being followed by debility and relaxation, and thus by an increased flow, is too roundabout to be accepted without more exact proof than has yet been adduced.

Furthermore, if the contraction of the arteries going to a part were the cause of its redness, then in every instance that redness would correspond in extent exactly to the area of distribution of the artery concerned; but it is by no means proven that such is the case. We have in an inflammation of a small portion of skin, a deeply reddened central spot, from which in every direction the color gradually shades away into the hue of the normal tissue. It would seem more natural to seek at the focus of the disturbance for its prime cause, than at one or more points at its margin or outside of it.

Lastly, the disturbing cause cannot be shown to act upon the arteries at all. It may indeed be alleged that it is by a reflex nervous influence communicated to them, but this is a mere supposition, not upheld by positive observation.

I would therefore urge that the fulness of the blood-vessels in an inflamed part is due to the increase which takes place in the attraction of blood

to the tissues. Not that the interchange between the blood and the tissues is rendered more active, (although such may be the case in the early stage of the process,) for if this were so, nutrition would be promoted; but merely that the irritated part calls for more blood, and the call is responded to. If the irritation continues, and amounts to inflammation, the overstimulated tissues are unable to dispose of the blood they have acquired, which therefore stagnates, blocking up the vessels; and as the general circulation goes on, the fresh blood which comes to the part must find a passage elsewhere. Hence ensues a crowding of the vessels in the neighborhood of the focus, and hence the gradations from the point of greatest obstruction outward to the healthy parts around.

Whether the current be merely rendered slower, or checked altogether, it is easy to see why throbbing should take place in the arteries supplied in the part affected, and why more blood should flow from an opening in the corresponding vein. A greater resistance than usual is encountered by the arterial wave, which therefore spends its force upon the walls confining it, and is more readily perceptible through them. And as the capacity of the part to receive blood is lessened, while more, or at least as much as usual goes to it, the flow will necessarily be more forcible wherever the resistance is taken away.

I am glad to be able to adduce, in support of these views, the authority of so able a writer as the late Dr. Alison, of Edinburgh, who uses the following language:—

"From all these facts we think ourselves justified in inferring that inflammation consists essentially in a local increase of a vital property of attraction existing among the particles of the blood, and between them and the surrounding textures, and with which other vital properties are connected and simultaneously excited. That the proximate cause of inflammation, although affecting the constitution of the blood, does not reside in the blood only, but primarily in the agency on the blood of the solids through which it passes in the capillary vessels, appears clearly from the limitation of the disease to a certain locality in the body, from the fact of its easy reproduction, for a long time, or for life, in the vessels which have once been the seat of it, and from other facts to be mentioned as to inflammatory effusions."*

In further illustration of this subject, let me recall my military simile. The ordinary distribution of supplies by the quartermaster's and commissary's department corresponds to that of nutritive material and oxygen to the various parts of the body by means of the circulatory system. When from any cause, such as hardship or disaster, any portion of the army is in need of larger supplies than usual, a special requisition is made for what is wanted, which is furnished, it may be, by the ordinary channels, but in greater quantity than usual. And thus it might happen that the roads leading to the spot occupied by the troops in question should be blocked up by the wagon trains carrying their supplies. Now according to the view I have advanced, it would be just as reasonable to say that this whole occurrence was due to an effect produced upon the road over which those wagon trains pass, or to the increased number of these trains, as to ascribe all

* Outlines of Pathology and Practice, 1844, p. 84.

the phenomena of inflammation in the frog's web to an increased calibre of the vessels or to the augmented quantity of blood contained in them.

And the difference between congestion and inflammation may be readily set forth by means of the same comparison. If those wagon-trains had been sent by mistake or want of judgment to a point where they were not needed, or if, in the ordinary course of operations, their return to headquarters had been impeded by the rise of a stream or the burning of a bridge, the same blocking up of the roads would have taken place. And so, if blood is in any way furnished to a part in excess over the amount needed for its nutrition, the vessels will be congested and the whole part turgid. This may be the case from various circumstances which need not be mentioned here. The condition produced does, in its visible appearances, more or less closely resemble inflammation—but the other phenomena are either wanting or far below the degree they acquire in the latter state. Such a congestion approaches much more nearly to the form of disease known as chronic inflammation, which will come up for study hereafter. Suffice it to say now, that the state of congestion is more transitory, and affects much less deeply the process and the power of nutrition in the part. In congestion the vessels are quite as passive, quite as much irresponsible, so to speak, as they were shown to be in inflammation; in fact, I think it may be asserted that congestion is one of the elements of inflammation, and may exist by itself, just as the pain may

in neuralgia. Neither congestion nor neuralgia constitutes inflammation; but in this latter state we have a congestion dependent upon and kept up by changes in the nutrition of the part, and a neuralgia, a painful condition of the nerves, likewise due to certain changes, and rendered persistent just so far as those changes are so. Remove the cause of the inflammation, and the congestion and neuralgia will disappear, as will the other phenomena.

Perhaps it is scarcely necessary for me to mention that there are other causes of congestion, which are purely mechanical; and that the state thus brought about, as for instance in a foot by the constriction of the leg, or by gravitation, may be properly called passive congestion. Such a state of things is clearly different from that which has just been discussed.

I would, then, ascribe the redness of inflammation to the abnormal fulness of the blood-vessels, by reason of the increased attraction of the tissues in this state of things for the blood; the conclusion by no means following, that the tissues can maintain their ordinary relation to this increased amount of blood, since many other facts go to prove that what we can best designate as the powers of life are diminished instead of being augmented.

The abnormal flow of blood to the part is due, then, not to any *vis â tergo*, but to the *vis â fronte* exerted by the tissues. Neither the heart, the arteries, nor the capillaries can of themselves determine any changes in the supply to be furnished at any time—they can only perform the duty which falls to them. They are not more active, and they cannot

be more passive, than they are in the healthy state of the whole economy.

The *heat* in inflammation may naturally be considered next, as being not only, after the redness, the most palpable phenomenon of that morbid state, but as being closely connected with it in its causation. And it was by the combined existence of these two conditions, heat and redness, that the name inflammation, like the corresponding Greek word phlogosis, was suggested.

That a part which is inflamed has its temperature raised above the normal standard for that part, cannot for a moment be doubted; but the degree of this elevation is generally much less than would be supposed either by the patient or by the observer. The patient is apt to be misled, because not only are the nerves of the affected organ rendered unduly sensitive to heat as well as to the causes of pain, but they are the seat of subjective sensations resembling those due to extrinsic influences. The heat and the pain are both actually felt, but they cannot be clearly distinguished the one from the other; the patient can scarcely tell how much of his discomfort is due to heat and how much to pain, but each renders the other more severe.

On the other hand, the surgeon is liable to overestimate the rise of temperature, partly because his imagination is excited by the redness and the other phenomena, or perhaps by the very name which he gives to the morbid state; and every one knows how inaccurate a test of heat sensation is, even in the observation of differences.

Certain it is, that the thermometric changes pro-

duced by this condition are much slighter than would be supposed. Hunter held the view that the temperature of an inflamed part never exceeded that of the central portions of the body; and the statement is confirmed by Andral and Gavarret, and by most other writers.

A greater increase of heat takes place in some inflammations than in others. When the grade of the disease is high, and the redness very marked, when in other words the inflammation is acute, the rise of temperature is proportionately great. When on the other hand the morbid state has been for some time existing, when the changes are going on more moderately, as for instance in cases of the repair of injuries, after the first stage has been passed, the heat will be only slightly elevated, if at all, beyond its natural standard.

It is necessary here to anticipate a statement which must be made in connection with the constitutional symptoms of inflammation, viz., that the system at large passes into a febrile condition under the influence of this local disturbance. And as one element of this disorder, the temperature of the whole body rises in some degree. Hence, although the part itself may seem to be very much heated, it will be found that the central organs are affected in like manner and in equal proportion.

A fact familiar to all who have been in the habit of making post-mortem examinations will bear somewhat upon this subject. When a body is opened soon after death, or when it has been kept in a warm room, the air of which is so damp as to prevent the body from cooling by evaporation,

the heat felt by the hand of the operator introduced into any of the great cavities will be so great as to be very disagreeable. Sometimes it may even be said to be pungent. And yet this is at least no greater than that of the same body during life; it is certainly not above 98° Fahrenheit.

The heat of an inflamed part is therefore increased positively, but only to a limited degree; it never passes beyond that of the central organs, and varies somewhat with the degree of activity of the morbid process. Its mode of production must now be inquired into.

And in the first place we may assert that there is no superadded source of heat; whatever is the origin of the caloric developed in the normal structure must also give rise to that which occurs in inflammation. Hence we have to go back to the study of healthy nutrition, to ascertain what those processes are by which the temperature of the living tissues is kept up, and which, being increased in activity when the change in nutrition begins which we call inflammation, induce a correspondingly augmented development of heat.

As has been already remarked, no law of nature is set aside in the living body, any more than in inorganic matter. If a force is overcome, it is by the opposition to it of a greater force; if an effect is produced, it is by a direct and legitimate cause. Hence in assuming the actuality of a vital force, we do not by any means set up a mysterious agent by which phenomena are irregularly and spontaneously brought about. It cannot be affirmed that the vitality of an organic cell increases by the mil-

lionth of a degree the amount of heat which would be developed or made latent by the same chemical changes taking place between the same atoms if they were in the state of inorganic matter.

So far as is now known to science, there are three sources of heat: mechanical, chemical, and electrical changes. According to the views set forth by Prof. Tyndall, in his admirable lectures on "Heat Considered as a Mode of Motion," it seems probable that all these may be in strictness regarded as identical—the clashing of atoms being the proximate cause of every development of heat. But for our present purpose it will be sufficient to take the grosser statement first made.

As to the mechanical sources of heat in the living body, the only one as yet known is the friction of the various parts. And although for obvious reasons the avoidance of friction is one of the ends most clearly aimed at in the structure of all organized beings, it is probable that there is enough to give rise to some degree of heat. This, however, cannot be appreciable to any means of testing which we possess, nor can it be separated from the chemical processes which incessantly take place during life, and in fact until the atoms composing the body have been finally resolved into their original independence. Hence it may be left out of the account.

The chemical sources of heat may be more readily investigated. Chief among these are the combinations of oxygen with the other elementary substances.

Nutrition, consisting in the taking up from the blood by the tissues of the food they want, and of

oxygen; and depuration, consisting in the giving up to the blood by the tissues of the effete matters they no longer want, are the two great processes which begin and end with life. The result of these processes is the formation of carbonic acid, water, and ammonia. Chemically speaking, they consist simply in a series of combustions, incessantly going on, and demanding an equally incessant supply of fresh fuel. And these combinations are just as surely productive of heat as if they went on in a furnace, between elements wholly inorganic.

For, upon the principle before stated that atoms, by their association into organic forms, are in no way exempted from the ordinary laws of physics, but simply acquire a corporate character; the union of one equivalent of carbon and two of oxygen must, here as elsewhere, give rise to a certain definite degree of increase of temperature. As Professor Tyndall would express it, the clashing of those atoms would convert their motion into heat.

To recur to our army illustration, the men who are formed into a company or regiment do not lose their individuality, but are simply massed for a certain purpose. The discharge of one man's musket will produce just the same effect as if he were a civilian; his aim is no truer, his powder no more energetic, than if he had no comrades. It is in the moral effect, and in the combined and massed action of the whole command, under definite control, that the advantage of military organization lies.

In support of the statement that combustion is the source of the heat of the animal body during life, it may be well for me to adduce the authority

of standard writers on physiology. Dr. Carpenter ascribes the production of animal heat to the burning up of fatty and other matters within the body. He says:—

"It may be stated as a general fact, that every change in the condition of the organic components of the body, in which their elements enter into new combinations with oxygen, *must* be a source of the development of heat. And as we have seen that a considerable part of the carbonic acid and water which are exhaled in respiration, is formed within the body by the metamorphosis of its own tissues, and that this metamorphosis is promoted by the active exercise of the nervo-muscular apparatus, it follows that in animals whose habits of life are peculiarly active, while the temperature of the surrounding medium is sufficiently high to prevent its exerting any considerable cooling influence over them, the combustive process thus maintained may be adequate for the maintenance of the temperature of the body at its normal standard. This seems to be the case with the great carnivorous quadrupeds of warm climates, and with certain races of men who lead a life of incessant activity like theirs. But whenever the cooling influence of the atmosphere is greater, or the retrograde metamorphosis of tissue takes place with less activity, some further supply of heat-producing material is required; and this is derived either directly from the food, or from a store previously laid up in the body. Although the albuminous and gelatinous components of the food may be made, by decomposition within the body, to yield saccharine and oleaginous compounds which serve as an immediate *pabulum* to the combustive process, yet this metamorphosis involves a great waste of valuable nutritive material; and the needed supply is much more advantageously derived at once from those farinaceous or oleaginous substances, which are furnished in abundance by the vegetable kingdom, the latter also by the animal. No reasonable doubt can any longer be entertained, that the production of heat by the combustive process is the purpose to which these substances are destined to be subservient in the bodies of herbivorous animals and of man; and the results of experience in regard to their relative heat-pro-

ducing powers, are in precise accordance with the indications afforded by their chemical composition."*

It would be interesting to quote the further arguments by which this able author defends the position that the amount of oxygen consumed bears an exact proportion to the amount of heat evolved, and therefore that the former is the true source of the latter; but it would occupy too much time at present. I must, however, refer to another view, against which Dr. Carpenter argues at some length:—

"The influence," says he, "which conditions of the nervous system are shown to possess over the function of calorification, has led some physiologists and even chemists to the conclusion that the production of heat is essentially dependent upon nervous agency, of which it is one of the manifestations. But, as Prof. Liebig justly observes, 'if this view exclude chemical action, or changes in the arrangement of the elementary particles, as a condition of nervous agency, it means nothing else than to derive the presence of motion, the manifestation of force, from nothing.' That the production of heat in living bodies may take place without any possible assistance from nervous agency, is manifest from the phenomena of vegetable heat already referred to; and there can be no reasonable doubt that the source of this production is a true combustive process. And the evidence afforded by the post-mortem production of heat in the human subject conclusively points to the same result; more particularly as the elevation of temperature observed in the brain was uniformly *less* than that which was manifested in other large organs. But the phenomena enumerated† (and many others that might be cited) can scarcely be accounted for, without admitting that the nervous system exerts an important modifying power upon the temperature of the body, which may be either elevated or depressed through its agency;

* Principles of Human Physiology, Am ed. p. 412.

† Certain results of experiment and observation on injuries of the nervous system in man and lower animals.

and the question now arises whether this operation takes place through the influence which the nervous system exerts over molecular processes of nutrition, secretion, etc., or through some more direct method. It can scarcely be denied that the first of these channels affords not merely a possible, but also a probable, means for the exercise of such influence; but still it is difficult to conceive that any great effect can be thus produced, since, as already shown, it is not so much in the growth as in the disintegration of textures, that heat is produced by the oxidation of their components. On the other hand, from the close relation which has been shown to exist between the vital and physical forces, it can scarcely be regarded as improbable that the nervous force, generated by molecular changes in the nervous substance, may manifest itself under the form of heat, just as we know that it manifests itself (as in the electric fishes) under that of electricity. And thus it is quite conceivable that one mode in which alimentary materials may be applied to the maintenance of animal heat, may consist in their subservience to these molecular changes, which seem to take place in the nervous substance with more activity than in any other tissue; and thus a large measure of caloric may be generated through the immediate instrumentality of the nervous system, notwithstanding that the ultimate source of its development lies (as in the chemical theory) in the oxidation of the elements of the food."*

Dr. Draper, who, like Liebig, inclines to the explanation of all physiological phenomena upon chemical principles, says:—

"In every instance we assert that the production of animal heat is due to oxidation taking place in the economy, and giving rise to carbonic acid, water, and other collateral products."†

From these views, Dr. Dalton, of New York, in his "Treatise on Human Physiology," dissents strongly. According to him,—

"Animal heat is a phenomenon which results from the

* Op. cit., p. 417. † Human Physiology, p. 182.

simultaneous activity of many different processes, taking place in many different organs, and dependent, undoubtedly, on different chemical changes in each one. The introduction of oxygen and the exhalation of carbonic acid have no direct connection with each other, but are only the beginning and the end of a long series of continuous changes, in which all the tissues of the body successively take a part. Their relation is precisely that which exists between the food introduced through the stomach, and the urinary ingredients eliminated by the kidneys. The tissues require for their nutrition a constant supply of solid and liquid food which is introduced through the stomach, and of oxygen which is introduced through the lungs. The disintegration and decomposition of the tissues give rise, on the one hand, to urea, uric acid, etc., which are discharged with the urine, and on the other hand to carbonic acid, which is exhaled from the lungs. But the oxygen is not directly converted into carbonic acid, any more than the food is directly converted into urea and the urates.

"Animal heat is not to be regarded, therefore, as the result of a combustive process. There is no reason for believing that the greater part of the food is 'burned' in the circulation. It is, on the contrary, assimilated by the substance of the tissues; and these, in their subsequent disintegration, give rise to several excretory products, one of which is carbonic acid.

"The numerous combinations and decompositions which follow each other incessantly during the nutritive process, result in the production of an internal or vital heat, which is present in both animals and vegetables, and which varies in amount in different species, in the same individual at different times, and even in different parts and organs of the same body."*

It will be seen that these views, although differing from those of Carpenter and Draper, embody still the idea of a chemical origin of animal heat. And it seems to me that although other molecular interchanges besides mere oxidation undoubtedly

* Op. cit., p. 228.

take place in the tissues, they very generally include the latter, and are subordinate to it in their relation to the phenomenon we are now studying.

Permit me to lay before you one other quotation, from the "Leçons de Physiologie" of M. Milne-Edwards, a French physiologist of great authority:—

"This physiological combustion, as we have seen, takes place in all parts of the organism, but not everywhere with the same degree of activity; consequently the mode of distribution of the heat in the interior of the animal economy may throw some light upon the way in which the chemical work of nutrition is shared. In fact, when the thermometrical differences existing between the different parts of the body of a bird or a mammal are carefully observed, it becomes at once evident that these inequalities cannot depend solely upon the greater or lesser facility with which the animal heat is sent out among the various organs, but that they must depend, in part, upon the local differences in the degree of activity of the chemical changes in the living tissues, which changes give rise to the development of this heat. But the study of the varieties in temperature of the different parts of the body is less simple than might at first be supposed, since this temperature is influenced by that of the parts through which the blood has previously passed. In fact, the circulating blood is the grand equalizer of the interior temperature of the organism, at the same time that it is the alimentive source of the combustion of which the evolution of animal heat is a consequence. Our knowledge on this subject is as yet but limited; but according to the researches of M. Cl. Bernard, we see that the liver is of all the organs that in which the molecular movement is the most active.

"In introducing very small and sensitive thermometers into different arteries and veins in a living animal, M. Cl. Bernard has established remarkable differences between the temperature of the blood going from the heart to certain organs and that which, having traversed these, returns toward the centre of the circulatory apparatus. Where the blood returns from parts exposed to causes of considerable chilling, as for instance the limbs, the temperature of the

venous blood was found to be lower than that of the arterial; but where the loss of animal heat is but slight, the temperature of the blood current was found on the contrary to be higher after its passage in the capillary vessels than before it reached the interior of the living tissues. This rise of temperature was almost always very sensible in the blood which had circulated in the thickness of the wall of the digestive tube, but became still greater after the passage of the liquid through the portal system.

"In vigorous dogs, M. Cl. Bernard found the temperature of the blood in the hepatic vein to be often 41° (C.) [= 105° Fahr.,] or even higher. He found also that the substance of deeply-seated tissues was in general hotter than the blood passing away from it.

"It is probable that the kidneys are, like the liver, the seat of marked generation of heat, for M. Brown-Séquard has found that human urine, at the moment of emission, had a medium temperature of 39·5° (C.) [= 95·1° Fahr.,] and was therefore notably hotter than the majority of the organs of the body."

We have therefore a very great weight of authority in favor of the combustion-theory of animal heat. And I submit that unless it can be shown that in an inflamed part there is some superadded source of this condition, something which does not exist in any degree in the normal state of things, the rise of temperature which is observed in inflammation must be due to an exaggeration of the combustive process proper to health.

An observation which I have frequently made of late lends additional support to this view. In cases of hospital gangrene, where one portion of a large wound is healthy, or more properly healing, and the remainder of it is sloughing, there is a very great difference perceived by the hand in the temperature of the two regions. The sloughing portion will be much hotter than the other. Now this process of

sloughing is essentially one of oxidation; for if the wound is mechanically cleaned, and a dressing applied which will not supply oxygen, while it protects the tissue from contact with the oxygen of the air, the gangrene will be checked. Here then is an actual combustion or burning up of the organized elements, with production of heat.

It must not be forgotten that while, as maintained by Dr. Dalton, there are other chemical changes going on everywhere in the substance of the tissues, there is also in every case oxidation as an essential constituent of nutrition and secretion; and hence that this latter source of heat can never be done away with in the living body. If it were possible to isolate the other changes, and to show that they were productive of heat when so isolated, it might be asserted that oxidation was only one of a number of processes by which the temperature was maintained. The ground which I assume to be tenable is, that the main source of animal heat is the combination of other chemical elements with oxygen; and that in inflammation the activity of this change is so much increased as to render the affected part hotter than it normally is. How far other subordinate agencies are concerned in bringing about the same phenomenon, can scarcely be determined; but there is no reason to think that such agencies are more than subordinate. A point which will hereafter be considered is the suspension of the other or functional changes in parts which are inflamed, and whose temperature is unduly raised; and this fact seems to show that such increase of heat is owing to the oxidation, which still goes on.

LECTURE III.

PHENOMENA OF INFLAMMATION CONTINUED — SWELLING; CAUSED MAINLY BY FULNESS OF BLOOD-VESSELS; ALSO BY ENLARGEMENT OF TISSUE-ELEMENTS, AND BY DEPOSIT OF NEW MATERIAL BETWEEN THEM—EFFUSIONS—PAIN; SUBJECTIVE AND OBJECTIVE—ALTERATION OF FUNCTION—CONNECTION BETWEEN NUTRITION AND FUNCTION—ALL THESE PHENOMENA ARE COEXISTENT, BUT ARE UNEQUAL IN PROPORTION — CHRONIC INFLAMMATION — ERYSIPELAS — INFLUENCE OF INFLAMMATION ON THE GENERAL BLOOD-MASS—CONSTITUTIONAL SYMPTOMS OF INFLAMMATION, OR SYMPTOMATIC FEVER.

In my lecture of last week, I endeavored to set forth the rationale of the abnormal heat and redness which mark the state of inflammation; taking the ground that the former phenomenon was due to the more abundant circulation going on in the part, and that this found its explanation, not in any force exerted by the vessels, or in their debility or relaxation, but in the augmented attraction of the tissue-elements for substances contained in the blood. As to the rise of temperature, it will be remembered that it was ascribed to the abnormally increased activity of the combustion which in the state of health is the source of animal heat.

We have now to take up for study the third of the phenomena of inflammation,—the *swelling*. And it needs no very extended observation to show that this symptom varies much in its degree in different cases. Some tissues swell much more quickly, and

to a greater extent, than others—mainly because the mechanical obstacles are less. Wherever parts are bound down by strong and inextensible fasciæ, or are themselves dense and firm in structure, the degree of actual swelling will be less, but the effort at its production will be the same; and the tension thus caused often gives rise to very severe suffering.

One cause, and the most obvious one, of this swelling, is the fulness of the blood-vessels. The existence of such an abnormal fulness has already been pointed out; that it is competent to give rise to swelling, is clear from the fact that the same result follows from purely mechanical distension, as for example when a string is tied around the finger so as to arrest the flow of blood through the veins. Another instance more to the point is to be found in the swelling which accompanies physiological congestions, as in the case of the erectile tissues. Here the amount of swelling is often very great, and can only be explained as due to the gorging of the vascular system of the part, since by means of minute injections, we can artificially imitate in the dead subject the distension of the vessels, and produce a similar swelling.

There is, it may be, a stage of inflammation in which the fulness of the vessels is the sole cause of the swelling which exists; but so far as we know, this is only the very earliest stage. Perhaps it might even be more properly called a preparatory or transition state between health and actual inflammation; so that if the morbid process were arrested at this point, and the normal state of things restored, inflammation would not really have oc-

curred at all. And here the distinction may again be drawn between mere hyperæmia, such as might result from mechanical causes, and the congestion which is due to increased activity of the life-actions of the part, whether physiological or pathological. In the first case, as for example when a string is tied around the finger, the whole of the distal portion of the finger will be equally affected by the backing up of the venous current. In the second case, the extent of the congestion is determined by that of the influence of the exciting cause. For instance, in any of the erectile tissues, the change of condition affects all the parts of a certain system. It is not only the penis that becomes enlarged and congested in sexual excitement, and this by the mere pressure of the erectores muscles over the veins, but there is an increased flow of arterial blood into the organ, and this takes place also in the scrotum and testes.

Evidently there is here, in physiological language, a consensus of parts, and not a mere accumulation of blood such as takes place from a mechanical cause. And I contend that a state like this must involve the existence of a *vis â fronte*, an attraction, the limits of which are determined by those of the function concerned.

If now we substitute for the normal and physiological stimulus a pathological one, this also will influence the parts to a certain extent and degree in each case. And by the extent and degree of this influence will be determined the extent and degree to which the attraction of the tissues for the blood shall be augmented. Hence will ensue, first, a fill-

ing of the blood-vessels of the part upon which the disturbing cause acts, and a proportionate amount of swelling. Such a course of things is very commonly seen when a splinter gets into the skin. All around the point of injury the vessels fill with blood, and soon a little territory of redness and swelling is noticeable. If the foreign body be withdrawn, the congestion will very probably pass off, and the redness and swelling disappear, in a short space of time.

There are two other possible sources of swelling besides this filling up of the blood-vessels. One is an increase in the size of the tissue-elements of the affected part; the other is the deposit of new material between them.

Let us first inquire into the degree of importance to be assigned to the former of these conditions.

Any increase in the size of the tissue-elements must be due either to an actual process of growth in them, or to an infiltration into them of some material not nutritive in its character. But although such growth might take place in the stage of mere irritation, it is contrary to what we know of the effects of inflammation upon the powers of life to suppose that it can go on when the latter state is fully developed. A part which is inflamed is always weakened; that is, it is less able to fulfil its function, less able to resist any disturbing or destructive influence. Examination of such a part, either in its grosser anatomy or under the microscope, always reveals a deteriorated condition of the tissues composing it. Hence the idea of a true growth as a constituent phenomenon of inflammation may be rejected.

The only material which the tissue-elements could take up by mere infiltration so as to increase their size, is serum. I have never seen this, and in fact do not know whether its occurrence could be a matter of observation, although it is conceivable. And it could not be of much importance, except as hindering still further the already impeded function of the part.

The third condition mentioned as giving rise to swelling is of more moment than either of those which have now been considered. It is the extravasation, or escape from the vessels, either of blood as such, or of some of its constituents, or of the peculiar substance so well known under the name of pus.

Those constituents of the blood which may escape are either the watery and saline portions,—the serum, or the fibrinogenous, thicker liquid,—the lymph. As to the former, it may readily be disposed of, so far as our present inquiry is concerned, since its effusion is neither constant in inflammation, nor necessarily an evidence of that state. Mere mechanical causes may give rise to its pouring out, as for instance in anasarca; and the probability is that it is never dependent on any other condition. When in any case it accompanies inflammation, it gives to the swelling the doughy character of œdema; and this is apt to occur in certain parts, such as the ocular conjunctiva, the prepuce, and the labia in women. In each of these cases, the tissues concerned are of a loosely fibrous structure; and when, in old or weakly persons, parts usually dense and firm become relaxed and flabby, the

swelling in any inflammation which may occur will in like manner be œdematous and yielding. How far in such cases the effusion of serum may be substituted for that of lymph, or to what degree the two substances may coexist, can scarcely be defined. Probably, however, such a substitution is possible; or rather, the blood being poor in quality, and the tissues possessed of but small formative or assimilative force, the serous portions of the blood only escape. In other cases, the blood being richer, and the tissues having more energy, an effusion of lymph, diluted by an admixture of serum, may be readily conceived of as taking place.

The special point to be noted is, that these effusions are not of a different nature, as are alcohol and water, but that one passes imperceptibly into the other, so that in fifty instances of inflammatory exudation, the material poured out might present as many different degrees of richness, pure serum being at the lower end of the scale, and pure lymph at the higher.

Let me say here that in the foregoing remarks I have made use of expressions, such as "effusion," "poverty and richness," and "formative force," which have a certain conventional value, but which must not be regarded as scientifically accurate. It will hereafter be our business to look into the subject of the origin and development of lymph, and then the force of these expressions, and their relation to the processes and qualities denoted by them, will be more readily estimated.

The swelling in inflammation is therefore due primarily to the fulness of the blood-vessels; in the

second place, to the formation of a new substance called lymph, which crowds apart the normal tissue-elements; in the third place, perhaps, to an enlargement of those elements. Fourthly, it may be increased by the escape from the vessels of the watery portions of the blood, which may either dilute the lymph, or take its place altogether. Fifthly, if the vessels are in any way ruptured, there may be a hæmorrhage of more or less extent. Of all these causes of swelling, the only one which is constant is the first. The increase in size of the elements of the tissue is probably infrequent, and does not belong properly to the inflammatory process. The formation of lymph is apt to occur, but is not invariable, while the effusion of serum, like that of blood, is a mere accident.

One other condition of inflammatory swelling remains to be spoken of,—the development of pus. This, however, is unimportant here, except as modifying the shape and character of the enlargement; the shape, because it seeks the surface, and causes what is known as "pointing," the character, because its presence gives rise to fluctuation.

Pain, as a symptom of inflammation, is almost constant. It is wanting in some cases where the sensibility of the nervous system is lessened, and in others where that of the part involved is not naturally acute. Thus in old and imbecile persons, pneumonia may run its course to disorganization of a large portion of the lung-tissue without producing pain enough to call attention to the disease. A case of gunshot wound of the chest, the ball being imbedded near the apex of the left lung, which was

almost destroyed by the resulting inflammation, has recently occurred under my notice. From first to last, a period of more than four months, the patient made no complaint of pain.

This symptom is always marked where the structure of the part is such as to prevent free swelling. And hence it may be inferred that it is in great measure due to the pressure of the swollen tissues upon the terminal nerve filaments.

Another important source of pain is probably the heat evolved in the part by the abnormally active chemical changes going on among its elements.

Besides these causes acting from without, there is reason to believe that the nerve-fibrils are not only so involved in the abnormal process as to be morbidly sensitive, but so changed as to become the seat of subjective pains. Special sense seems to be abolished, where it exists in health, and the only capacity of the nerves distributed to the affected part seems to be for pain.

That the character of this symptom varies greatly in different cases, is a fact of which almost every one is aware from experience. It is aching, burning, stinging, itching, more or less severe, according to the part involved, the violence of the disorder, and the sensitiveness of the patient.

Where the terminal nerve filaments are in relation with a surface, as in the skin, the pleura, or the peritoneum, the pain is apt to be greater than where they are distributed through the mass of a solid organ such as the lung, liver, or spleen.

The singular fact has been often observed, that in some inflammations the pain is referred to a spot

at a distance from the actual seat of disease. Thus in coxalgia the knee is apt to be complained of, in the early stages at least of the affection. This circumstance finds its explanation in the distribution of the nerves which are the seats of the morbid feeling, and which, supplying but few terminal filaments to the point actually disordered, communicate to the cerebro-spinal axis the same impression as if the trouble lay at their final expansion. Something similar occurs when the ulnar nerve is compressed in its passage behind the inner condyle of the humerus, when the distress felt is all in the parts supplied by the nerve in its ulterior course. This transferrence of sensation is never met with, I believe, where the parts actually involved are such as when in health possess much tactile sensibility. It is to be specially noted that in such cases the pain is not of the ordinary character of that of inflammation, but is more neuralgic; patients who are old enough describe it as gnawing and wearing. Another fact of importance is that the pathological state of the hip-joint which gives rise to such pain is often, perhaps indeed in a very large majority of cases, not strictly speaking an inflammation; this condition may be developed to some extent as an incidental phenomenon, but the disease itself is a mere outcropping of a vice of constitution. I am aware that the doctrine is strongly advocated by some surgeons of experience, that the disorder in question is always produced by injury, but although this may be the exciting cause, there is strong ground for the belief that it merely gives a provocation, and calls forth, in a certain direction, tend-

encies which had lain dormant in the economy. Certain it is, that the scrofulous diathesis—to use a conventional term—is often strongly marked in persons who are the subjects of hip-joint disease.

In almost all cases of inflammation there is positive and continual pain; but when this does not exist, there is tenderness, either upon pressure or upon motion. In pneumonia, for instance, the act of deep breathing develops pain; in inflammation of loose and yielding parts, pressure does the same.

The pulsatile or throbbing character of inflammatory pain may be readily understood. A congested state of the vessels of a part, by which they are crowded against the resisting structures about them, will cause each beat of the heart to make itself felt, especially when the undue sensitiveness of the nerve-fibrils, which constitutes an element of the morbid state, is taken into the account.

One other symptom of inflammation, which ought perhaps rather to be regarded as an effect of all the others now mentioned, remains to be noticed,—the *alteration of function*. During the irritative or preliminary stage, the function may be performed in excess; as the process goes on, it is interfered with and set aside; and still later, it may be restored, but not in its healthy character.

This alteration of function, either in the way of abolition or impairment, may be due either to mechanical causes, or to such structural changes as necessarily attend the morbid process. Perhaps it would be more correct to say that the structural changes, in all cases of true inflammation, lie at the root of the disorder of function, which is

brought about either mechanically or chemically. For although functional disorder may occur without any positive evidence of any morbid change of structure of the part, we cannot for a moment suppose that such change of structure can occur without being attended with derangement of function. An assemblage of chemical elements is endowed with a certain corporate power, by virtue of which the affinities of each are in no way suspended or abolished, but simply conjoined with those of all the rest for the attainment of a common end. Now it is no more possible for one of these chemical elements to be altered without influencing the aggregate result, than, to bring up again my army simile, for one man or ten men in a company to be demoralized without so much being detracted from the efficiency of that company; and the evil may spread much further if those men by their example and conversation infect their comrades.

We are speaking now of the performance of function; and if the structure and composition of the cell are, as it seems but common sense to assume, intimately connected with, and essential to the end which the cell is intended to answer, any change in that structure or composition must at once affect the fitness of the cell to its end.

Allusion has before been made to the intimate connection existing between nutrition and function. But in the state of inflammation two of the most important elements of nutrition are materially interfered with—the supply of blood is in excess, while the assimilative power of the tissues is lessened, and the influence of the nervous system is

changed just so far as the terminal nerve-filaments are involved in the disease, or affected secondarily by its phenomena. Hence, exactly to the degree in which these abnormities are developed, will the process of nutrition and its close dependent, function, be impaired.

Now in speaking of the general subject of animal heat, I took the ground that the temperature of the living body was kept up by the chemical changes going on in the tissues, and especially by those true combustions which result in the formation of carbonic acid, water, and ammonia. But as these very changes are closely linked with, and essential to, the functions of all the organs, it might seem as if, when function was impaired or set aside, the heat of the affected part ought to fall, from the failure of its source. Common observation, however, testifies that the temperature rises, while we know also that function is interfered with. How is this seeming inconsistency to be explained? I think, simply by the fact that the oxidation or combustion goes on more actively, while the other and more special interchanges of material between the blood and the tissues are either hindered or checked altogether. Oxidation is indeed essential to function, and closely interwoven with it—but the latter does not necessarily ensue upon the former. When a function is performed, we may assert most positively that there has been an oxidation and burning up of the tissues concerned in its performance; but we now know well that such a combustion may take place, and yet the function fail.

There is an error into which those who are look-

ing into this matter for the first time are particularly apt to fall, although it may seem as if it were easy to avoid it. It is that of regarding these phenomena of inflammation,—the redness, heat, swelling, and pain, and the impairment of function, as successive in their occurrence; whereas they are all in existence at one and the same time, and are only studied separately for the sake of convenience. Let us try now to correct this error so far as it may have arisen in our inquiry.

The heat and pain attract the patient's notice first, generally, and the swelling is then perceived; sometimes, in parts which have mechanical relations with the flexure of a joint for instance, the swelling makes itself felt at the same time. The redness, in superficial parts, seems to be developed simultaneously with the heat and pain, while, except in the case just mentioned, the swelling is the last symptom to appear. Very often the impairment of function is almost or quite overlooked by the patient, seeming to be eclipsed in importance by the other phenomena.

But although, so far as the sensations of the patient and the casual observation of a bystander can be relied on, there seems to be a difference in point of time in the occurrence of the phenomena of inflammation, such an idea is at variance with the explanations of those phenomena before given.

For, the part being irritated, the morbid process begins in an entirely excessive and abnormal attraction of blood to it by the tissues; the vessels become more and more turgid, combustion goes on more and more rapidly, the nerve-filaments are

altered in condition and subjected to greater and greater pressure; while the tissues in which these morbid changes are taking place are less and less duly nourished, and more and more impeded in the performance of their function.

Surely in all this there is no succession, but the causes of the heat and redness, of the swelling and the pain, arise together, some of them being the same; and the part, from the moment of its manifesting any change from the healthy state, goes on becoming less and less fit for its duty until the disease has reached its height.

But while the symptoms of inflammation are thus uniform in the actual *time* of their occurrence, they are less so in their *proportion*. Perhaps the heat and the redness are more nearly constant in their relative degree than any other two of the other phenomena, and this for an obvious reason, in their common origin. The amount of pain is much more variable, and the swelling may range anywhere between scarcely perceptible enlargement and extreme deformity. To a certain degree, the swelling and the pain may be said to be in an inverse ratio; for when from mechanical conditions the swelling is limited, the pressure upon the nerve-fibrils is necessarily more severe. Another qualifying circumstance must, however, be mentioned; in some parts the nerves are so much more sensitive than in others as to be affected far more severely by a given amount of pressure.

The description and remarks now given do not apply to the state of chronic inflammation, in many respects. What the differences are between the

acute and chronic forms of the disease, may perhaps be as well set forth here as at any other stage of our discussion.

Chronic inflammation offers the same features as the acute, but differently proportioned one to another. There is always more or less redness, often very marked, sometimes of a deepness almost amounting to purple; but the color is apt to be more evenly spread, and less inclined to heighten about a focus than in the acute form of the disease. As a general rule, the heat is very much less developed, although, while the actual rise of temperature is less, the subjective sensation of burning may be extremely troublesome. Swelling is usually present, but like the redness it is more diffused than in acute inflammation; it is sometimes very marked in its degree, and is then often œdematous, and of a manifestly passive or mechanical origin. Pain is in many cases wholly wanting, or only slight, but there may be a good deal of tenderness. Function, if mechanical, is apt to be abolished; if it consist in secretion, it is more commonly disordered.

It would be easy, if time were less valuable, to go in detail into the rationale of each of these phenomena of chronic inflammation, and to show that they corresponded altogether in this respect with those of the acute. By analogous facts and arguments, we should find the redness to be due to fulness of the blood-vessels, the swelling to the same, with the addition of effusion; the objective heat to augmented rapidity of chemical change, the subjective to the state of the nerve-fibrils within the part, to which the pain would also be found attributable.

Chronic inflammation, whether it is an original or a secondary form assumed by the disease, is easily explained upon well-known principles. Its slight severity as compared with the acute, is due of necessity to a difference either in the exciting cause or in the part affected. Thus the condition which gives rise to it may be of gentle but continuous action,—or, the original disturbance having been severe, there is a tolerance acquired by the tissues which lessens very much the degree to which they are irritated by it. Such a tolerance may be manifested either by the nerves of the part or by its organic elements. And this explains the diminution of all the phenomena when an inflammation becomes chronic. The grade of all the morbid changes which take place in the part is lowered.

One or two points must be specially touched upon in this connection. The redness sometimes remains very marked; and in all cases it is readily increased by any renewed irritation. The cause of this is to be found in an actual change in the relative size of the capillary vessels and the tissue-elements. Passive as the vessels still are, they are distended in the state of acute inflammation, and, the part not returning to absolute health, no force is exerted upon them to restore their normal size. The tissue-elements are still impaired in their nutrition, and their bulk is probably often diminished; while the excitement which first augmented the attraction they exert upon the blood is still kept up, although perhaps in a greatly less degree.

I have had occasion to speak of the tolerance acquired by the tissue-elements as well as by the

terminal nerve-filaments, when an irritation is long kept up. This is entirely consistent with another fact, viz., that any new stimulus makes itself felt more severely than it would if applied to the healthy organ. And this irritability is associated, in the case of the individual tissue or part, with diminished power of life, just as it is in the aggregate or system at large. As every one knows, a man whose strength is broken down by disease, inflammatory or otherwise, is more readily disturbed by any morbific agency than he was when in health. The quickness and intensity with which he feels any such influence is in fact proportioned, not to his vigor, but to his weakness.

By this expression, power of life, we mean the tenacity with which the corporate character before alluded to as possessed by organized matter, and the energy with which the functions belonging to that corporate state are exercised. It is the essence of this which is beyond human understanding; its mode of manifestation is easy to observe.

We have now surveyed the phenomena of inflammation, which were laid down as essential to it,—and have inquired into the rationale of those phenomena. I would once more insist upon the position which I took in my first lecture as to the identity of this process, whenever and wherever it occurs. Such a theory does not conflict with the fact that the grosser characters of the disease may be modified by its causes, by states of the system, by the anatomical structure of the affected part, or by peculiarities in its normal constitution, by sanitary or remedial measures.

The inflammation which surrounds a small-pox pustule is identical, in my opinion, with that which affects the skin when a foreign body imbedded in it is the source of the mischief. It is essentially the same as that which occurs in the brain, the lung, or the bladder. In every one of these instances we have the same phenomena, the heat, redness, swelling, pain, and impairment of function. Whatever other conditions may be present are secondary and incidental to these principal ones.

To look a little further into this. Take a case of cystitis, or inflammation of the urinary bladder. Here there is a copious deposit in the urine of pus and mucus, with epithelium from the lining membrane, and phosphatic crystals. There is much distress in micturition, and in the performance of function by the other abdominal viscera. The nervous system may be greatly disturbed by the suffering undergone. But all these symptoms, and any others which I may have omitted to speak of in this hasty enumeration, are simply incidental to the inflamed state of a part or the whole of the urinary bladder. And the disease lies in that layer of the wall of this hollow organ which intervenes between the muscular coat and the mucous membrane. Here, upon examining after death, we find developed the physical characters of inflammation—and it is easy to see that with these the heat and pain, and the impaired function, were intimately associated during life.

To a want of rigid accuracy in the separation of the essential phenomena from their secondary consequences, may be attributed much of the obscurity

which still clothes this subject. Unless it can be shown, that there is an essential difference between the process of inflammation as manifested in different organs, or under what have been called its different forms, we must believe that here as elsewhere in nature the law of simplicity of type is adhered to.

I can scarcely leave this subject without alluding to one point which seems to me important, and which may be better spoken of in this connection than elsewhere.

Among the various forms of inflammation mentioned by Hunter, was the erysipelatous. Now there is at first sight great propriety in calling erysipelas, as well as the erythema which is so often confounded with it, a form of inflammation. But I submit that a closer scrutiny will show that erysipelas is a special disease, which excites inflammation as an incidental condition,—and which, moreover, modifies this condition to a marked degree. Put the poison of erysipelas in relation with the system, or with certain parts which are readily influenced by it, and it gives rise to an inflammatory change in the nutrition, the symptoms of which differ in their relative proportion from those of the same process as excited by the presence of a foreign body. But, and herein lies the point for which I argue, the starting-point of the difference is not in the inflammation itself, but in the cause. And hence, although we may with propriety speak of erysipelas as a disease, or of inflammation as one of its invariable but incidental phenomena, we cannot use the term erysipelatous inflammation correctly, except in a wholly conventional sense.

Your attention has now been directed to the phenomena which are essential to the process of inflammation, as they exist in their full development.

Upon reviewing the ground over which we have passed, I think it will appear that these phenomena all depend on the tissues for their origin and maintenance. The gorging of the vessels with blood, it was argued, was due to an influence exerted by the organic elements or cells upon that liquid; redness was thus produced, and swelling, the latter being also due to certain effusions. The heat was ascribed to chemical changes going on between the blood and the tissues, and the pain to morbid alteration of the nerve-fibres and the relation between them and the surrounding parts; while the function must of necessity owe its disorder to some abnormal state of the agents which carry it on in health,—the tissue-elements.

We leave out of the account, therefore, all the notions which have prevailed so widely among writers on pathology in regard to "action of the vessels." The question of contraction or relaxation of the capillaries, primary or secondary, is wholly immaterial. Those tubes are neither strengthened nor weakened, but simply, as in health, passive—yielding to a pressure from within when the current flowing along them is increased in volume, and in like manner yielding to a pressure from without when that current becomes smaller.

Such, at least, seems to me to be the legitimate result of the reasoning we have employed in the interpretation of our facts. Nor do I know of any fact in support of other theories, or which has ever

been so adduced, which has been overlooked in our inquiry. It is in the tissues that the true theatre of the inflammatory process is to be placed. They are the seat of the healthy life-actions, and when the character of those actions is changed so as to constitute disease, it is still in the tissues that the change resides. In either case, the material structure is wholly passive, and normally or abnormally, obeys the influences exerted upon it.

Upon the views which have been presented in regard both to normal nutrition and to inflammation, it must be obvious that according to the extent and degree of the latter there will be a change wrought in the character and composition of the blood. For in health the relation between any organ or mass of tissue and the blood flowing through it is, as has been already said, one of incessant interchange. To use the expression of Treviranus, quoted by Paget, every part stands to all the rest in the character of a secretion. More than this, it throws into the blood again the materials which have resulted from its own waste. And should the amount of material taken or given by it be altered in quality or quantity, the relation it bears to the blood contained within its vessels is in a corresponding degree altered. But as this blood is carried on in the course of the general circulation, and the supply continually renewed to the affected part, it is clear that a certain influence must be exerted upon the whole blood-mass of the economy. In the case of a large part or organ, it may be readily seen that the effect so produced would be appreciable—while if the extent of the abnormity

were but small, the change in the general blood-mass, although no less real, would be too slight to make itself felt.

Again, there are some organs which have special functions to perform in modifying the composition of the blood. Such are, for example, the lungs, the lymphatic glands, the spleen. Inflammations of these organs would naturally be supposed to affect the blood more directly than would those of other parts. And it is found by experiment that such is the case; although the opportunity for observation has not as yet been extensive enough to give accurate data in regard to all the points embraced in this statement.

When, therefore, we come down from these general facts to the special enumeration of the blood-changes which occur in inflammation, we meet with great difficulties. Notwithstanding the labor that has been spent in the study of this subject, the most earnest and skilful investigators have been foiled in their endeavors to clear it up. All that is known in regard to it may be soon stated.

The red corpuscles of the blood drawn from any one laboring under inflammation show, when examined under the microscope, a tendency to adhere one to another by their flat sides so as to form rouleaux. This phenomenon is observed also in the case of pregnant women, and in horses as a normal condition. No satisfactory explanation of it has ever yet been offered, but as Paget remarks, it would seem to belong not to the blood in the vessels, but to that which has been removed from the sphere of life. When it exists, it is one cause of

the formation of the buffy coat,—the whitish or pale yellow layer at the surface of the blood-mass; the specific gravity of the rouleaux being greater than that of the same number of red corpuscles would be if scattered apart, so that they sink rapidly, leaving a portion of the clot uncolored.

The number of red corpuscles in the blood is probably diminished in inflammation, if it is altered at all. For in view of the close mutual relation between the blood and the tissues, it is difficult to see how the nutrition of the latter can be disturbed without affecting that of the former. And it is equally difficult to imagine that the nutrition of the blood can be interfered with, without each of its constituents sharing in the trouble. But the red corpuscles are the most highly developed of those constituents; their presence is the main feature of the distinction between blood and lymph, and in the condition recognized as poverty of the blood, they are diminished in quantity. Whether or not they are only the colorless corpuscles in a highly developed state, physiologists do not agree; the evidence does not seem to me to favor such an idea.

As to the white corpuscles, it may be regarded as certain that their number is very much augmented in many inflammations; and the same may be said, with less reservation, of the fibrin. I mention these two constituents of the blood together, because the fact has long been recognized that they bear a certain relative proportion to one another, and that they cannot be separated with any exactness in our investigations. To quote again from Virchow:—

"It is very rarely that a considerable increase of fibrin takes place without a simultaneous increase in the colorless blood-corpuscles, and therefore the two essential conditions which we meet with in the lymph, we again meet with in the blood. In every case of hyperinosis we may rely upon discovering an increase in the colorless corpuscles; or, in other words, every irritation of a part, which is abundantly provided with lymphatics, and freely connected with lymphatic glands, occasions also the introduction of large numbers of colorless cells (lymph-corpuscles) into the blood."

The idea has been entertained by some observers, that the increase now alluded to of the colorless corpuscles and the fibrin, was a local change, or rather that only the blood flowing through the affected part was involved in it. But the weight of modern authority, that of Jones, Bennett, Virchow, Paget, Follin, and in fact of most writers of our day, is in favor of the idea that the whole blood-mass is modified in this way.

It is by microscopic examination that we ascertain the abnormal quantity of the white corpuscles in the blood. The increase in the amount of fibrin is shown by the size and tenacity of the clot formed in the blood when drawn. And here perhaps it may be best remarked that while the former condition must obviously exist in the blood as it flows along the vessels, the latter is considered by many physiologists as occurring after the blood is withdrawn from the sphere of life. With this question, however, we are not now concerned—the fact of the increase stated is beyond a doubt. According to the analyses of Andral and Gavarret, Simon, and other observers, the amount of fibrin, normally 3 parts in 1000, is augmented in inflammation to 4, 5, or 6.

Besides the change in quantity of the fibrin, it has been mentioned that its coagulation takes place more firmly than in health,—and this fact was formerly considered as an evidence of greater organizing power. But the position of fibrin in regard to organization is now thought to be unimportant, the idea that it was albumen undergoing developmental change having been abandoned; and it is considered rather as a result of degeneration. And this is clearly in agreement with another view of recent origin, viz., that inflammation itself is not a state of increased, but of diminished vigor.

Permit me again to quote from Virchow some remarks in relation to this increase in the amount of the fibrin and colorless corpuscles in inflammatory blood. He says, in connection with an argument for the local origin of all these changes in the general blood-mass:—

"Those organs which with especial frequency exhibit this peculiar combination of a so-called phlogistic state of the blood with a local inflammation, are generally abundantly provided with lymphatic vessels, and connected with large masses of lymphatic glands, while all those organs which either contain very few lymphatics, or in which these vessels are scarcely known to exist, do not exercise any influence worth naming upon the amount of fibrin in the blood. Former observers had already remarked that there were inflammations occurring in very important organs, as for example in the brain, in which the phlogistic crasis was, properly speaking, not at all met with. Now it is precisely in the brain that we have scarcely any evidence of the existence of lymphatics. In those cases, on the contrary, in which the composition of the blood is earliest altered, namely in diseases of the respiratory organs, we find an unusually abundant net-work of lymphatics. Not merely the lungs are pervaded by, and covered with them, but the pleura also has extremely numerous connections with the lymphatic sys-

tem, and the bronchial glands constitute almost the greatest accumulations of lymphatic-gland-substance possessed by any organ in the whole body."

The amount of albumen in the blood seems to be increased by the occurrence of inflammation, although not in so exact a proportion to the fibrin as would be supposed upon the idea which prevailed until recently, that the latter was developed from the former.

Along with the diminution of the number of red corpuscles, and the increase in the amount of fibrin, albumen and colorless corpuscles, in inflammatory blood, the quantity of water is increased. From 790 parts in 1000 it often, in the analyses reported by Simon, in his "Chemistry of Man," rose to over 800. At the same time the salts held in solution were greatly lessened. The rationale of these facts I am not prepared to give, nor is it perhaps important.

To sum up then the changes which are observed in the blood of persons laboring under inflammation, and which, according to the views I have attempted to set forth, are due in great measure to the influence of that local condition,—the red blood-corpuscles are diminished, as are also the salts; while the white corpuseles, the albumen, the fibrin, and the water are largely increased.

And without entering into detail, I may again say that these changes are in some degree influenced by the normal function of the part concerned. Thus, according to Simon's analyses, both the albumen and the fibrin were found to be increased in larger proportion in pneumonia and peritonitis than

in other inflammations. In phthisis also the albumen was largely increased, the fibrin less so; but it is not certain how far the vice of constitution in this disease modified the effect of the incidental inflammation.

The occurrence of inflammation is generally attended,—always if the part involved is large or important, and especially if the disturbance is suddenly brought about,—by a more or less severe derangement of the system. And it is obvious that no examination of the phenomena of this disease can be complete without embracing the symptoms which are thus secondarily induced. Having therefore discussed the local changes involved in inflammation, and those which ensue upon it in the general blood-mass, let us now take up the subject of irritative or symptomatic fever.

Peculiar difficulties invest the study of all constitutional diseases. Their mere phenomena are not hard to define, but to trace these to their several sources, and to point out their relations of cause and effect, so as to form an accurate idea of the whole process, is beyond our present powers of analysis. In proof of this it is sufficient to refer to the whole class of fevers. We know, perhaps as exactly as we ever shall, the natural history of the various types of fevers, and of the several members of each group; we can state the lesions apt to be associated with each. But after all the earnest and careful study bestowed on these disorders by intelligent observers in various countries, many important questions in regard to them are still unsettled. For example, nothing is definitely known of their

causes. When malaria is spoken of, it is a mere conventional expression; so also is contagion. No one has ever yet been able to give anything like an accurate description of the nature or mode of operation of either.

And when we consider the constitutional irritation produced by local inflammations, we find that the greater simplicity of this morbid state does not make it any more easy of real comprehension.

Fever is a condition so often met with as to be familiar both by experience and observation to the layman as well as to the professional inquirer. It affects the entire system, either in the way of pain or of derangement of function. Irritative or sympathetic fever is less apt to be ushered in by well-marked chill than is that which may be called specific, as for instance that due to malarious influences. Chilliness and wandering pains are, however, often met with when this condition is first set up. A positive decline in surface-temperature may occur, or there may be only a subjective sensation without such a fall.

Very soon, even where the first symptom is chilliness, the temperature rises over the whole body, the skin becomes flushed and dry, the eyes bright, the breath hot; all the secretions are checked, the pulse is greatly increased in quickness and volume, and the breathing is somewhat hurried. More or less mental excitement always occurs, and sometimes amounts to actual delirium.

Different persons present these symptoms in varying degrees, according to the impressibility of the nervous system. Other circumstances, such as the

nature and severity of the local trouble, and the more or less plethoric habit of the individual, also influence the general disorder.

Another fact strongly marked in regard to these phenomena, is the change which they undergo at different times of the day. This, I need scarcely observe, is common to all febrile states, as well as to some other morbid conditions.

A patient with inflammation will be very apt to be more feverish in the latter part of the day, and at night, than during the forenoon; and if the general symptoms are kept up for several days, or a week, or more, this cyclical rotation will hardly fail to be noticed.

There are three channels by which the influence of local lesions may be communicated to the system at large—the nerves, the blood-vessels, and the lymphatics.

It is not difficult to see how these channels are respectively made available. When the changes already mentioned in the nervous element of any inflamed part are considered, it is clear that there must be as it were a report made to the central organs, the brain and spinal cord, of the disturbance. Hence a reflex influence will be exerted upon all of the peripheral portions of the nervous system. This effect will be in direct ratio to two things: the severity of the disturbing cause, and the sensitiveness of the entire apparatus.

In a person, therefore, whose nervous system is either naturally or abnormally impressible, a comparatively slight local lesion will induce severe general symptoms. No difference in the degree of these

symptoms will exist between two persons of like sensitiveness, if the local disturbance be of like gravity in each.

The blood-vessels and the lymphatics may be made channels of communication between the affected part and the general system in one or more of three ways. Either the circulating liquid, the blood or lymph, may be changed to an appreciable degree in passing through the part, or it may be made the vehicle for distributing the products of disease; or the vessels themselves may become the seat of inflammation, which extends along their walls until it constitutes a source of trouble.

Now in most cases, perhaps in the great majority of cases of inflammation, it is the nervous system by which the general disturbance is excited.

And from the facts established by daily experience in regard to reflex actions and sensations, the mode in which a local disorder may thus disturb the whole economy is not difficult to conceive. We can just as readily explain how the irritation from an inflamed breast is transmitted to the cerebro-spinal axis, and thence outward again to the heart and arteries, as how the tickling of the sole of the foot causes a reflex contraction of the muscles of the leg. Sometimes, indeed, as has been already mentioned, the reflex influence of an inflammation is still more plain, as when one breast is inflamed, and the other becomes so secondarily, without any direct cause for such a disturbance.

One point must be noticed here. The amount of fever is not always in apparent proportion to the severity or extent of the local lesion. Thus a small

carbuncle will give rise to very annoying febrile symptoms, while an injury involving a much larger part may scarcely excite the pulse. But it is evident in the first place that the system may be much more impressible in one case than in another, and secondly, that the character of the local trouble will have much to do with that of the general disturbance. Nay, it may be that the same systemic state which determines the liability to fever determines also the occurrence of the local lesion; such is probably the case in the instance just mentioned, of a carbuncle. So it would be, too, with poisoned wounds; although here the objection may be raised that we cannot exclude the influence of a change in the blood-mass by the poison introduced.

But herein lies the very difficulty which besets all physiological as well as pathological studies, namely, that of separating certain chains of cause and effect from those which surround them or are interwoven with them. Could we only isolate the nervous system for purposes of experiment, or the vascular, we might clear up some very intricate questions.

It is not, however, merely the pain caused by the inflammatory state which gives rise to fever, for we have, in that most obscure and ill-defined condition known as neuralgia, far more intense pain without febrile movement. And here again the confession must be made that the difference between these two states is not yet known. The facts we have, but no satisfactory explanation of them has yet been given.

As to the effect produced on the system by local inflammations, through the blood-vessels, it is evident that much depends on the bulk of the affected

part. For example, it cannot be conceived that a leg or arm should be extensively inflamed without a material influence being exerted upon the blood-changes going on in the system. For in such a case a large portion of the circulating blood would be in relation with the affected part; the transfer of chemical elements from the blood to the tissues and from the tissues to the blood would be, within the affected area, altered or interfered with; and upon the view already mentioned, that each part or organ stands in the relation of a secretion to all the rest of the body, it is manifest that there would be an accumulation to some extent of certain ingredients in the blood, which should normally be removed, and a removal from it of others which should normally be retained. Perhaps also there might be in some cases a new formation, as it were, of unwholesome materials in the blood.

Should the affected organ be one which has a special function, such as the liver or spleen, it is obvious that these excesses or deficiencies, or derangements of relation between it and the circulating blood, will be more marked and more injurious than where the function is lower in the scale.

Should the affected organ have an office directly connected with the formation or normal changes of the blood, such as the spleen, or the mesenteric glands, the trouble induced by its inflammation may be readily explained.

And this disturbance will be more marked in cases of single organs, than in such as are double, where that of one side, if unaffected, can substitute that of the other.

As to the importance of the lymphatics as a means of communication between inflamed parts and the system at large, it is somewhat difficult to speak positively, the same obscurity existing here as in the case of the blood-vessels. But no doubt can exist that the extension of the local disease along the lymphatics, or the taking up in the current flowing in them of morbid materials, are the two modes in which they are most frequently the agents of such communication.

With regard to the production of febrile symptoms, which is the point now in question, we may probably leave the lymphatics out altogether. There is no evidence of their taking any part in this in ordinary cases, otherwise than as modifying the formation of the blood so far as they are themselves altered locally. It may be that in dissection-wounds, for instance, a poison is carried along them, which by entering the circulation gains access to the nerve-centres and acts as an irritant, so as at least to influence the character of the febrile movement. But in the fever of ordinary frank inflammations, whatever change may take place in the processes carried on by the lymphatics is probably wholly subordinate to that occurring in the nerves and blood-vessels.

To sum up, then, the inflammatory or sympathetic fever usually met with is to be ascribed to the irritation of the nervous system, manifesting itself by reflex phenomena; in some degree also, when the local disorder is extensive, to the disturbance of the regular blood-changes of the economy, and in a very much less degree to the alteration of the lymphatics or their contents.

But the fever, although the inflammation is not materially diminished, is generally noticed to subside after a few days are past.

This may be accounted for partly by the tolerance acquired by the nerves of the affected part, as well as by the cerebro-spinal axis,—partly also by the change which so often takes place in the local state, when suppuration is established. In most cases there is a manifest relief derived from this or any other discharge, so far as the heat and pain are concerned; and the area of the redness is also much diminished.

Another circumstance which goes to account for the subsidence of the general excitement is the tolerance acquired by the nervous centres, so that the effect of the local trouble is less felt by them.

Perhaps also the blood-changes are so equalized by the various organs that the condition of the blood approaches more nearly to the healthy standard, so that whatever influence this liquid, disordered by the local disease, may have had in giving rise to the fever, is withdrawn either wholly or in part.

It would therefore appear that the febrile movement is as it were the effect of a shock upon the cerebro-spinal axis, due to a disorder of some part of the periphery of the nervous system. This shock may be either primarily depressing, excitement occurring subsequently, or it may act at once as an irritant.

LECTURE IV.

CAUSES OF INFLAMMATION—THEY MUST OPERATE ON INDIVIDUAL CELLS—THEY MAY BE MECHANICAL, CHEMICAL OR VITAL—IRRITABILITY—REFLEX NERVOUS INFLUENCES—DIRECT RESPONSE OF CELLS TO STIMULATION—MECHANICAL CAUSES—CHEMICAL—VITAL—RATIONALE—LAW OF IRRITABILITY, FUNCTIONAL, NUTRITIVE AND FORMATIVE—LAW OF REACTION—LAW OF MUTUAL RELATION OF PARTS—LAW OF SYMPATHY—SPECIAL APPLICATIONS OF THESE LAWS—TENDENCY TO ADHERE TO NORMAL TYPE—CONTAGIOUS INFLAMMATIONS—INFLUENCE OF HEAT AND COLD—TUBERCLE AND CANCER AS CAUSES OF INFLAMMATION.

On the last occasion when I had the honor of meeting you, gentlemen, we were occupied with the study of the phenomena of inflammation. One of the general statements which I made in my first lecture, with regard to this disease, was that it was essentially a derangement of nutrition; and this led me to discuss at some length the rationale of the process by which the tissues are normally maintained in life. We then took up one by one the changes in the state of a part, which, when occurring together, warrant us in saying that such a part is inflamed. The character of these changes, and the circumstances upon which they are dependent, were detailed. The influence of the complex local disturbance on the general mass of the blood next claimed our attention; and finally, a sketch was given of the constitutional symptoms which make up what is so well known under the name of fever.

Let us now go back of the fully developed state of inflammation, and examine into the causes by which it is brought about—by what agencies a part, duly nourished and regularly fulfilling its function, is so disturbed as to become gorged with blood, swollen, hot, painful, and incapable for the time of continuing its normal office in the economy.

I have before had occasion to urge the fact of the passive obedience of matter to external influences—its entire want of any power of spontaneous action. This idea is of importance in connection with our present subject. Every change must be owing to a direct and adequate cause. And in so saying, I do not mean merely to make the general statement that disease cannot arise spontaneously, but to reduce this to its lowest terms,—to assert that of the millions of cells going to make up any part or organ, no single one can become deranged without a special and sufficient influence acting upon it to change its state. This idea is manifestly parallel to the one which was urged in regard to healthy nutrition and function,—that each special cell or tissue-element has its own nourishment to receive, its own waste to repair, its own work to do.

Let me again bring up my military comparison. In a body of soldiers under fire, not one will be killed or wounded unless he himself is struck. And yet it would be quite as reasonable to account for the death or wounding of one soldier by saying that he was among a number of others who were injured in like manner, as to say that one cell of the liver is involved in inflammation merely because others are.

Of a dozen men exposed to the contagion of small-pox, not one will take it because the rest do, but in every case the occurrence of the disease is ample evidence that the patient was directly subjected to a sufficient influence of the poison.

There is not between the tissue-elements anything analogous to the force of example. The men of a regiment may be morally contaminated by the cowardice of a few; but they cannot, as was before remarked, be physically injured by bullets which do not strike them. And dealing with the cells and the intercellular substance we have to do only with individuals on a smaller scale.

Perhaps I ought here to say that I do not mean to ignore the influence which the state of one cell or other tissue-element may have upon those adjacent to it. Thus it is quite rational to admit that the electrical state of one such cell may induce a similar state in its next neighbor—and so on until a large number perhaps are involved. Perhaps a force similar to that known in chemistry as catalysis—a certain change of state being induced in one atom or combination of atoms by the fact that its neighbors have undergone or are undergoing a like change—may exist between the elements of the organism. But in every such case, whatever be the influence exerted, it is brought to bear directly upon the individual which is the subject of it. And it must be remembered, when we speak of electricity and catalysis, that they belong to the imponderable forces. They have to do only with the relations obtaining between material elements, causing, so far as we have yet been able to ascertain, nothing more

than a change in the arrangement of the atoms entering, for instance, into a chemical compound. This change may indeed be so momentous as to affect the affinity between the constituents of the compound, and thus to break it up; but this separation I take to be incidental only to the main case.

Given certain atoms in a certain state of combination into similar sets, and a change in one set may induce a corresponding change in another set; but no amount of electrical or catalytic force can induce anything more than such a change—can add an atom or subtract one.

In any case, however, my original statement remains unimpaired,—that no element of any organized tissue can be affected, either within the bounds of health or in the direction of disease, without a sufficient cause acting immediately upon it.

It will perhaps be noticed, and possibly it might by some be objected, that in the views just expressed the cells or tissue-elements alone are spoken of; that no allusion is made to any influence exerted on the vessels or nerves of the part. How far such an influence may be regarded as necessary or important in the causing of inflammation, we shall presently have to inquire more particularly. But I may anticipate by saying, that the view I shall endeavor to uphold will correspond with that advanced in connection with the subject of normal nutrition and its variations, viz.: that it is the tissue-elements whose maintenance in life and in the performance of their several functions is of paramount importance in the economy. Changes which do not affect them are of trifling moment. To them the vessels are

passive ministers, the blood a mere pabulum. The cutting off of their supply of food may cause their death; the gorging of them with an excess of it will of itself only hamper their functions. I shall try to show that unless a cell is directly influenced by some legitimate cause of the inflammatory state, it will not enter into that state. In other words, I would regard the cell as the agent of healthy life and function, and as the true theatre of whatever morbid change may take place.

If now we consider the influences to which the physical organization of man is subject, we find that they may be in general terms stated to be mechanical, chemical and vital. So far as *the mind* by its changes affects the body, it does so through that incomprehensible connection which exists between the former and the nervous system. Our observation begins outside of this, which we cannot attempt to explain. The brain only, as the physical exponent of the mind, may be directly acted upon by it; but this influence is brought about through the connection just mentioned, and is, so far as it is within the sphere of human inquiry, altogether analogous to those exerted upon other organs. For instance, overexcitement of the mind may induce inflammation of the brain; but all we know about it is, that the physical structure of the brain has had an undue amount of work demanded of it, or has been abnormally stimulated, just as the liver or kidney might have been, and that the result is a certain morbid change in its nutrition.

Another remark seems to be necessary before

taking up the consideration of the separate classes of causes mentioned as giving rise to inflammation. The mechanical and chemical agencies are not in strictness distinct from the vital. They are so only because up to a certain point they can be followed; but they must there be met by the same answering susceptibility which every living tissue possesses to the changes which occur around it, and without which no manifestation of life is possible. It would be idle, in the present state of biological science, to try to explain this; and it must be a qualification merely of our reasoning.

The influence of mechanical causes in giving rise to inflammation is not very difficult to trace; although it is often complex in its character. A heavy blow, or a gunshot, tearing and bruising the tissues, will obviously disturb all that portion of the body affected by it, killing or destroying some cells, and deranging the balance of others. It cannot be imagined that such an injury should be inflicted on living tissues without the neighboring parts suffering irritation. And the cells thus irritated have but one way of responding to the stimulus—they attract more blood. They at once begin to carry on a more rapid interchange of chemical substances with the blood, to undergo more rapid waste, and in some degree a more rapid renewal. Further, there is at first, although it may be for so short a time as to wholly escape notice, an increase in the activity of function of the part.

I would, if possible, qualify these statements so as to make them express more accurately the idea of the utter passiveness of the tissue-elements; but

the poverty of our conventional language makes it difficult to do so. If sulphuric acid is poured on carbonate of lime, it decomposes it, taking hold of the lime and driving off the carbonic acid. We speak of the chemical process as going on very actively, although we know that the acids and the alkali are passively submitting to the circumstances under which they are placed, and could no more refuse to obey the inexorable law of their affinities than a plummet could resist the attraction of gravitation.

A man who is irritated can control himself, or he can deliberate in what way to wreak his resentment; a dog, less highly endowed, will bite at what annoys him; the living tissues neither know nor feel, but blindly obey the physical law under which they exist. It is partly from their connection with the mind or instinct which knows and feels, partly from the seeming irritation of the perceptive and responsive faculty which belongs alone to an immaterial principle, that we have been led to apply to their passive changes expressions which would seem to assign such a faculty to these unwitting atoms.

Let me remark here that in speaking of the irritability or irritation of tissue-elements, the idea of pain is not at all involved. The susceptibility to pain, or to any sensation whatever, is possessed exclusively by the nervous system. It is unnecessary for me to enlarge further on this point, which would indeed have been deducible from other statements which either have been or will be made in the course of our discussion.

Another element which enters into this irritation

of tissues by mechanical causes, and which complicates its study, is the effect which cannot but be produced upon the nerve-filaments of the part. We have already seen that there is abundant proof of the influence of the nerves upon nutrition. Now if in any way the peripheral portion of the nervous system is subjected to local excitement, it is well known that there will be an influence transmitted along the different nerve-trunks to the spinal cord or to the brain, and thence again a response sent out, constituting what is known as reflex action. And this may or may not be a matter of sensation, according to the character and degree of the impression, and the state of the brain at the time. For instance, if the mind is earnestly engaged upon a certain object, absorbed in it, severe injury may be sustained without the cognizance of the brain, food may be taken without any excitement of the sense of taste, and other external impressions pass unnoticed; while very complicated muscular actions may be gone through with in an automatic way. It is as if the report of a disaster befalling a part of an army, or a requisition for supplies, should be received and acted on by a subordinate officer, without previous reference to headquarters.

Now the question next comes up, can this want of cognizance include the whole nervous system—is it possible for the tissues to act for themselves, to respond directly to stimulation, as the soldiers of a suddenly attacked force might fire upon their assailants without waiting for the word of command? I think we must believe that they can do so.

The idea of such a power is not without analogy

in the normal state of the tissues. One of the best known and most palpable instances of this kind is found in muscular fibre, which will contract under the influence of stimulants directly applied to it, when wholly separated from nerve-structures. Todd and Bowman, Carpenter, Dalton, and other authorities in physiology might be quoted in support of this point, did time permit.

But if such a property exists in muscular fibre, it would be hard to show that it could not belong also to other structures. Moreover, it does not simplify matters at all to assert that all stimuli must take the roundabout course of reflex action in order to reach the tissues. By so assuming, we add another element to the process, but it is one which is itself beyond our comprehension—one which may be described, but cannot be explained.

Nor does the division of the main nerve supplying a part prevent that part from becoming inflamed. I do not know what might be the effect of the cutting off of all the nervous supply, but certainly there may be a very great interference with innervation, with an actually increased tendency of the tissues dependent upon it to pass into the inflammatory state. A case illustrative of this will be mentioned in connection with those causes of inflammation which for want of a better term I have classed as vital.

One other statement, although somewhat premature, seems to bear upon the immediate subject of discussion. In the case of an incised wound, dividing nerves and vessels alike, we find that inflammation ensues quite as quickly and in as great a degree on that edge, which is of necessity cut off from reflex

influence, as on that which is still in relation with the central nervous system.

I think therefore that (always keeping in mind the idea that the tissue-elements simply obey passively the influences brought to bear upon them, and hence that their *activity* can be regarded only as a figure of speech) my assertion holds good, that the primary effect of irritation upon them is to increase their attraction for the blood, and to promote, although it may be but for a very short space of time, the discharge of their function.

Subsequently, and just so long as the effects of the mechanical injury last, this state of deranged nutrition will be kept up. If there is violence done to the tissues so that they need repair, the disturbance will not be wholly allayed until the repair is completed, and the normal condition of things restored. And let me remind you that in my first lecture I took the ground that inflammation was always a state of disease. It is therefore set up as the result of the injury done, and not as a means of repairing it; it is maintained so long and in such a degree as the abnormal state which makes repair necessary involves irritation.

The statements now made apply, I think, to every form and grade of mechanical violence. It may be in some cases, as when a blow is received which is just severe enough to induce actual inflammation, that the phenomena of this state are developed only for a short time, and without any further consequences—the part soon returning to the condition of health. In other cases, as for instance when a limb is crushed, or a foreign body forced into the

tissues, the incidental phenomena of suppuration, ulceration, adhesion, may ensue; but the essentials are the same.

To sum up then what has been said as to the effect of mechanical causes of inflammation; they act directly upon the tissue-elements, irritating them and disturbing their nutrition. Whatever agency the nerves may exert by reflex irritation is secondary and non-essential, powerful though it may be. And according to the statements made in my former lectures, this derangement of nutrition accounts for the redness, heat, swelling, pain, and disorder of function, by which we know the part to be inflamed.

The study of the chemical causes of inflammation need not detain us very long. The living structures are made up of atoms subject to the same physical laws as if they had not been brought into that mutual relation which constitutes organization. So far as those atoms are concerned, indeed, the bringing of them together to make up a cell or a fibre is a merely temporary and accidental circumstance. The hydrogen and oxygen which are one day, as water, associated in the formation of a tissue-element, may the next day be either free, or newly combined in an inorganic compound. Not a single one of the ultimate constituents of the body is in its essential nature endowed with life. Upon the cessation of this function, the giving up of their charter, if I may so speak, the corporation is dissolved, and every individual member of it is set free.

Hence, if for instance a drop of sulphuric acid is placed upon the skin, it at once attracts the water of that tissue, and thus deprives the cells of an im-

portant compound element in their structure. But in so doing it must of course interfere with their nutrition, and may carry the interference so far as to destroy their life. The neighboring cells are likewise affected, but in a less degree; they are stimulated, and inflammation is the result. We have here also the dead cells acting as mechanical irritants, and thus adding to the disturbance.

Another instance of the production of inflammation by a chemical cause is seen when intense heat is applied to a living tissue. Not only is the water of the part boiled away, but the other constituents are wholly changed in their relation; they may be all driven off in vapor, the carbon alone remaining. Here then is a foreign body to be gotten rid of, while a powerful stimulus, which however belongs rather among the vital causes of inflammation, is applied to the surrounding textures.

It will be noticed in each of the instances adduced of mechanical and chemical causes of inflammation, that these agencies can only become operative in this way upon living tissue. No amount of violence done to a dead body, or to unorganized matter, by cutting, scalding, burning, the application of acids, will produce anything like inflammation. And the same may be said of those structures, such as the epidermis or the hair, which, although still in connection with the living frame, and even performing a function, mechanical as it is, are no longer the seats of the nutritive process.

It is only when there is a nutrition to be disordered, then, that inflammation can occur.

We approach now a difficult part of our subject,

—those causes of inflammation which I have called vital; which consist in agencies which affect the special conditions of life, apart, so far as can be observed, from any mechanical or chemical change. From the remarks made a moment ago, it may be seen why I qualified my original division of the causes of inflammation into mechanical, chemical and vital. The difference between these agencies lies, not in the changes to which they respectively give rise, but in the mode in which they do so. And hence they are not clearly defined one from the other, in their relation to the tissues. A severe blow upon the skin, or the application of a drop of sulphuric acid, must obviously act in different ways, although they bring about the same result; and the chilling of the skin which causes a bronchitis is just as clearly operative in still another way. In all, living tissue is irritated, and responds to the irritation; but in the third instance we have to do with a peculiar susceptibility, not only of single cells, but of the organism as a whole. Those causes of inflammation which I would call vital are often such as would be totally without effect unless they were brought into relation with the living animal; such as, to take but one example, the gonorrhœal poison.

It appears, therefore, that while living tissues, whose nutrition is going on, are alone susceptible of becoming inflamed, this disease may arise either from such causes as act also upon inanimate matter, mechanical and chemical agencies, or from such as are entirely within the sphere of life. Now in the consideration of the two former classes of causes, we have stood only on the threshold of the real problem.

Given, we have said, a mechanical or a chemical force, capable of injuring the tissue or of changing its composition, by adding or subtracting atoms or disturbing the relation of those already combined in it, and the cells so acted on resent the interference, become irritated, and exhibit the phenomena of inflammation. Now when we take up the vital causes, we shall find that they also derange the nutrition of the organic elements upon which they act. How they do so, and even in some instances in what they consist, we do not know. They cannot be analyzed; sometimes they cannot even be described.

As has been seen, the action of the mechanical and chemical causes is exerted directly upon the tissues which become inflamed by them. In many cases, however, the vital causes operate most obscurely. Thus, if the small-pox poison be introduced into the system, we do not know why it should crop out at certain points of the surface, or at least by what influence those points are determined. Nor, in the case of metastatic abscesses, for example, have we any satisfactory knowledge either of the general cause inducing them or of the special cause by which they appear at some spots and not at others.

There are four laws which are well recognized in biology, which have an important bearing on this whole subject. One has been already spoken of; it is, that in all living tissues there is a susceptibility to irritation. According to Virchow, there are three forms of excitement or irritability,—the functional, nutritive and formative. Resulting from the first of these there is merely a more rapid discharge of

the duty, whatever it may be, of the elements acted upon by the stimulus. From the second, there arises a more energetic absorption of nourishment by the cells, etc., which already exist, so that they grow. Upon the third there ensues a formation of new elements, by the enlargement and division of those which previously constituted the tissue. Just so long as a part, or an organic individual, a cell, is being nourished and discharging a function connected with its nutrition, is it liable to any or all of these forms of irritation, or rather of response to irritation. Muscular tissue, areolar or fibrous tissue, gland-cells, may all be shown to undergo them. On the other hand, epithelial or epidermis-cells, when they have ceased to do more than fulfil a mechanical and protective office, are no longer capable of being irritated. The parts underlying them may be so strongly stimulated as to be actually inflamed; but the effete cells are wholly unaffected.

The second of the laws alluded to is that of reaction. After excitement there follows a state of depression; and conversely, after depression there follows a state of excitement. So familiar is this fact that I need hardly dwell upon it now; its importance to a knowledge of the origin of inflammation may be readily understood.

The third law is more complex; it is that a certain relation subsists between different members of the economy, which may be looked upon either as a balance or an antagonism. To some degree this may be readily understood. Thus, according to common experience, when the secretory function of the skin is active, as in summer, that of the kid-

neys is less so; when, in winter, the skin is chilled and rendered torpid, the balance is maintained by the increased flow of urine. The complexity of this law lies in its actual working; for we find the application of cold to the skin giving rise sometimes to inflammation or irritation of the kidneys, sometimes to a like disturbance of the bronchial tubes, sometimes to congestion or inflammation of the liver. Undoubtedly in each of these cases there is some intercurrent condition, perhaps several, to which the special direction taken by the disorder is owing. But even where this might be appreciable to human observation, it is apt to be overlooked.

Still another law, a fourth, may be laid down as governing the relations of the different parts of the living body. It is the law of sympathy—but its application is less wide than that of either of the foregoing. Certain organs, and these are generally such as are directly connected with the same or with closely allied functions, manifest a tendency to assume like states. Thus the womb and the breast, the mouth and the stomach, are apt to correspond in their variations. A striking physiological example of this is found in the consensus of nearly all the organs in the change which takes place at puberty. At this time, doubtless according to a law impressed upon the organism at its first entrance into life, there is a sudden increase of nutritive energy, manifested by all the organs, but apparently with special reference to the new capacity assumed by the generative system. Should this latter element of the change be wanting or interfered with, the others will be only partially devel-

oped, or perhaps will fail altogether. This complex fact we explain by saying that the rest of the system sympathizes with the generative organs in their excitement.

But what is the correct physiological meaning of this word sympathy? Are we to suppose that there is some mysterious sense residing in the brain, for example, by which it becomes aware that the stomach is disturbed; and that it then proceeds to assume a new condition, appropriate under the circumstances? Such an idea would be at variance with all the other phenomena of living beings, as well as of physics generally. A man cannot sympathize with another in trouble, unless he either feels or imagines that he is himself liable to the same or to like distress; and he obviously cannot be moved to pity by sufferings of which he has no knowledge.

Precisely analogous conditions are essential to what we call sympathy between different organs. If the derangement of one organ affects another, the latter must be capable of the same morbid change as that undergone by the former, and there must be between the two some channel by which impressions are readily transmitted.

Now when this sympathetic disturbance occurs, it is always of the same character in the two organs. We do not find that the excitement of one gives rise to depression of the other, although in the case of the antagonism before spoken of there might at first seem to be a relation somewhat of this kind. But in such organs as have existing between them a sympathy properly so called, the process is one of

transmission; in some way the change which takes place in one is communicated to the other.

It was remarked, when the subject of the influence of local disorders upon the constitution was under discussion, that there were three channels by which this might be effected—the vascular system, the lymphatics, or the nerves. And it was then argued that the last named of these channels was by far the most important in that particular process.

Upon very much the same grounds it may be asserted that the influence of one organ over another is communicated by means of the connection of both with the cerebro-spinal axis. I have repeated, so often that you may perhaps be almost weary of hearing it, that the blood-mass is wholly passive, receiving and giving whatever is thrown into it or demanded of it. And therefore, even if it be granted that the change in the blood passing through an inflamed part is the immediate cause of disturbance in the sympathizing organ, there must be still the susceptibility of the latter to be accounted for; otherwise, why should not every tissue which is in any way in relation with the circulating blood feel the influence alike? For the question is not now as to a systemic condition such as that of fever, but concerns a distinct local change, brought about indirectly by a previously existing change of similar character in another part.

We are brought much nearer to the ultimate analysis of this matter of sympathy by referring it to the nervous system. Here we have in the first place, beyond all doubt, the phenomena of reflex action. By tickling the sole of the foot we induce such an

impression upon the lower segment of the spinal cord that the muscles of the entire limb contract and draw it up. And this takes place even when all communication with the brain and upper portion of the cord is cut off by disease or injury.

An instance of reflex action in which the effect produced is more palpably, although not more really, distributed over a set of efferent nerve-fibres not corresponding to the afferent ones irritated, may be found in the bringing on of vomiting by tickling the back of the tongue.

It makes no difference that the exact mode of transmission of this agency is unknown; whether it be by a change in the electrical state of the nerves involved, or by some special force differing from all others in nature, the main fact remains as stated.

Here then is a property established as residing in the nervous system by which the phenomenon known as sympathy may be plausibly accounted for. Through the medium of the brain or spinal cord, and without of necessity any consciousness on the part of the patient, the morbid state of one part may be reproduced in another.

To sum up the statements thus far made as to the causes of inflammation: Mechanical or chemical agencies may be exerted directly upon the atoms of which living cells are composed, and the state of those cells may be changed. The cells have, in their corporate capacity as such, the property of responding to or obeying stimuli. After being in any way depressed, they react. Between certain sets of cells constituting organs, an antagonism exists, so that the depression of one organ

induces excitement or irritation of another. Between certain other organs, a sympathy exists, so that the influences brought to bear upon one induce secondarily a like state in the other.

Allow me to say here again, that in all the arguments I have brought before you, I have studiously sought to avoid what may be called physiological superstition—the setting up of a mystery in the shape of a vital force, independent of and opposed to the ordinary laws of physics. My endeavor has been, to take the facts which pertain to our subject just as they are; to explain them as far as the present state of science enables me to do so, and to offer nothing except on the basis of actual observation.

Let us now seek to apply the general statements made, to particular cases—to ascertain, as far as may be possible, the working of these laws in the production of the inflammatory state. This inquiry embraces all the classes of causes already mentioned. It calls for a more minute examination of the influence of mechanical and chemical agencies, and for the specifying of those which, for want of a better term, I have called vital.

Unless we have gone very far wrong in our reasoning hitherto, we must find the rationale of the operation of every cause of inflammation in its disturbance of the conditions of normal nutrition. Either the part to be nourished, the quantity or quality of the material supplied for this purpose, the arrangements by which this material is brought into contact with the tissues, or the innervation which is essential to the consummating of the process, must be impaired or interfered with.

Let us take first one of the commonest causes of this morbid state,—the application of heat. Touch the skin with a hot iron, and the first effect will be to alter the chemical relations of the constituent atoms of every cell with which the metal comes in contact, or to which it communicates its heat. The water is vaporized, the albumen coagulated, the nitrogen and some of the hydrogen and oxygen associated into ammonia, the other chemical constituents either set free or brought into new combinations. Only a part of the carbon, and perhaps an infinitesimal quantity of lime, silica and iron are left. Instead, therefore, of the normal living tissue-elements, we have a mass of inorganic material.

Along with the tissue-elements thus destroyed, will perish any nerves and blood-vessels which are distributed among them. Now we may place out of the account all these dead portions of tissue, as they are manifestly incapable of any further life-action, or of inflammation—and we have to inquire into what takes place in the neighboring and still living parts.

It is evident that the cells lying next to those destroyed must feel the influence of the heat in a marked degree—the next layer will be affected, but less powerfully—and so on outward in a diminishing ratio, until we come to tissue-elements whose health is undisturbed. And the direct effect of this heat will be to stimulate the cells, each one in exact proportion to the degree in which it is acted upon, and to induce a quicker interchange between it and the blood, a quicker performance of its function, and as a consequence of both these facts a

more rapid waste and renewal of its component atoms.

Probably the degree to which this stimulation is carried in those cells which sustain it most severely is so excessive as to overwhelm their efforts to respond to it. I use this figurative expression because it seems best to set forth the idea. In its capacity as a living being, each cell would obey the stimulus impressed upon it by discharging its regular duty more energetically; but the conditions of its normal performance of function are all interfered with, either by the excess of that stimulus or by the changes attendant upon it, and the result is simply an undue attraction of blood by the cell.

In the successive ranges of tissue-elements between this and the region of health, the degree of excitement will of course be shaded off in lessening grades—so that we come first to parts where the state is merely one of congestion, and then find this becoming less and less marked till it disappears entirely.

Thus far, no mention has been made of the change which must be produced in the nerves of the affected part. It would be impossible to suppose that no such change occurred. Without questioning whether it consists in an alteration of the electrical state of their component atoms, or in an impression made upon them as sensory organs merely, we may assert that there is carried along them a report, as it were, to the nearest ganglionic centre, if not to the cerebro-spinal axis itself. And upon this there is sent outward a response, so that the tissues are further excited by reflex action.

I have before argued that this influence of the nervous element is exerted upon the organic cells themselves, and not upon the vessels or their contained blood. It is without doubt, I think, an exaggeration of that function which the nerves fulfil in the normal process of nutrition—and has to do with the relation subsisting between the two main factors in that process.

So long as the local disturbance continues in any degree, just so long and just in that degree will there be this reflex influence of the nervous system of the part. I may illustrate it by a comparison with the muscular sense which keeps the cerebro-spinal axis constantly informed of the state of every fibre of the voluntary apparatus. Here there need not be any cognizance taken by the brain of the report so made. In the first access of the disturbing agency there may be sensation; but this gradually diminishes, either from the brain or the affected part acquiring a tolerance of the irritation—so that in the later stages of the disease we find one important element of inflammation disappearing, viz.: the pain. But even when the pain has thus subsided, there remains a susceptibility to pain—a tenderness, which depends on an abnormal state of the nervous filaments of the part, and is associated with an irregularity in the influence exercised by those nerve-filaments upon nutrition.

For the sake of completeness, it must be here again mentioned that this reflex action of the nerves may not only exhibit itself in the aggravation of the effect of the direct causes of the inflammation set up, but may be exerted also upon parts situated at

a distance from the original disturbance—so that when, for example, one eye is inflamed by the presence of a foreign body, by overstimulation in the way of work, or by any other cause, its fellow may be secondarily brought into the same morbid state —and so also with the breast or the ovary. Instances of this kind are much more frequent than those of entirely separate organs thus sympathizing with one another.

The explanation now given of the mode of action of one cause of inflammation seems to me to cover all the essentials of that morbid process: the redness, the heat, the swelling, and the pain. The inevitable sequence of such a derangement, disorder of function, does not need to be again dwelt upon—while the effusion of lymph or pus, or both, which would be apt to occur in a state of things such as that which we have been supposing, I have deferred noticing until a later period.

There is another idea in connection with this origin of inflammation, which I offer with some hesitation, lest it should seem to border upon that physiological superstition which I have before sought to disclaim. It is that there is in the organism an intolerance of any departure from its normal anatomical type. Thus the healthy skin is covered with epidermis; it receives no impressions from without except through the medium of this layer of organized although effete cells. If now this protective investment is in any way removed, or if there be a foreign body driven into the substance of the skin, it is evident that the proper anatomical relations of a portion of that tissue are changed.

And so also in the case of a fracture. The broken ends of the bone, themselves altered in their anatomical relations, are brought in contact with muscular and fibrous tissues and with nerve-fibres, which should normally be subjected to no ruder pressure than that which they exert upon one another.

In the instance of destructive heat before adduced, the living tissue-elements are exposed to direct contact with the inorganic remains of those which have lost their vitality—and in this circumstance seems to me to lie an additional source of irritation.

Every case of mechanical violence or chemical destruction of which I can conceive contains this change of anatomical relation as an element. And it seems to me that this mode of accounting for the irritation set up by foreign bodies or by dead portions of tissue is more philosophical, and more in accordance with the established principles of biology, than the one commonly adopted, that the tissues endeavor to expel the intruding or offensive substance. The normal anatomical relations of the tissue-elements are abolished; and this of itself constitutes an irritation. The applications of this idea in the explanation of phenomena which daily come under the notice of the surgeon are numerous.

Thus we find that a clean incised wound, *other things being equal*, heals more readily, and gives rise to much less inflammation, than a lacerated or contused one; because in the former case the disturbance of the anatomical relations of the tissue-elements concerned is less serious.

Again, of two foreign bodies, one of which is smooth, evenly-shaped, and without chemical ac-

tion, and the other is rough, jagged, and corrosive, the former will be borne much more quietly than the latter. A smooth, rounded leaden ball lodged in a tissue produces much less inflammation than a twisted and irregular fragment of a copper cap.

I have been led to offer in a somewhat discursive way some considerations which I had meant to bring before you in more exact order—but perhaps, to some of you at least, it will seem as if this discussion had been already sufficiently prolix.

There still remain some causes of inflammation to be mentioned, which present greater difficulties than those which have hitherto engaged our attention.

Certain constitutional conditions are connected with the occurrence of this local state. For example, in strumous subjects we meet with various forms of ophthalmia. I say various forms, not because the inflammation itself differs except in the proportionate prominence of its symptoms, but because the disease is excited apparently by varying local states, affects sometimes one tissue and sometimes another, and is thus made to assume what would seem on a superficial view to be diverse types.

Thus, in charitable institutions where children are collected from among the poorer classes, we sometimes see actual epidemics of the disorder known as phlyctenular ophthalmia—one or more pustules surrounded by an area of inflammation, involving the cornea superficially as well as the whole thickness of the conjunctiva. In other cases the ordinary strumous ophthalmia, with photopho-

bia and profuse lachrymation, occurs. In other cases again, the Meibomian follicles seem to be the chief seats of the disease.

Another constitutional cause of inflammation may be found in certain poisons introduced into the system. Thus the poison of small-pox, that of syphilis, and of many skin diseases strictly so called, may be said to act in this way. Analogous to these cases is that of the inflammations so often met with as sequelæ of enteric or typhoid fever, and so apt to end in suppuration.

In every one of these instances, however, let it not be forgotten that there must be a direct cause for the local occurrence of the disease—that every effect must have a legitimate parentage. Why small-pox pustules, or the vesicles of rupia, should occur in certain spots rather than in any others, we cannot tell—but that they are not sprinkled by mere chance, we may be very certain.

Gout and rheumatism might be added to the list, although I need hardly say that all pathologists are not agreed in so placing them.

But the most striking of all the instances of inflammation due to vital causes is one to which allusion has already been casually made, viz.: gonorrhœa. Here we find a purely local disease, and one which to all appearance is undistinguishable from any other inflammation of a mucous membrane, transmitted from one person to another by means of one of its accidental products. It seems as if the evidence could not be set aside that the urethra may also become inflamed from simple causes of irritation, and that the state so induced cannot be distin-

guished from that brought on by impure sexual intercourse. Whether the former can be propagated by contagion, like the latter, I do not know. At any rate, certain it is that pus may be in contact with the urethra, as in cases where it is discharged along with the urine (having been formed in the kidney or bladder), without any inflammation being excited—but that which owes its origin to a genuine gonorrhœa will, so far as we know, invariably give rise to a like condition in the mucous membrane of the urethra if applied to it.

Moreover, it must be noted that of the other mucous membranes, some are liable to take on a similar morbid state if touched by gonorrhœal pus, as for instance the conjunctiva, while others, such as the lining membrane of the nose or that of the alimentary canal, are unaffected by it. Here some special and unaccountable property is manifestly possessed by certain tissues, in virtue of which they always respond to certain irritants in a certain way, while others, for want of this property, never do.

Mention has now been made of the production of inflammation by the localizing of certain systemic disorders, or by the application of irritants under favorable conditions of the constitution, and by the contact of substances which have a special and direct irritating property. It will be seen that in all these cases there is evidently a stimulus brought to bear upon the part in which the disease occurs—the difference between them lying in the mode of localization or in the peculiar power which resides in the substance of irritating certain living tissues. The change which ensues in the part so influenced is

simply in obedience to the law of life, that organized matter, subjected to irritation, passes into a state which we call excitement, and becomes inflamed.

Another class of vital causes of inflammation is made up of those agencies which are primarily depressing, and of which the best example may be found in cold. The secondary excitement, which occurs according to the law that in living bodies such a reaction should follow depression, presents no features differing from those of excitement directly produced. We need not therefore allow it to detain us.

There remains to be considered a very interesting and important agency belonging among the vital causes of inflammation, to wit, the irritation of one organ by means of the depression of another.

To illustrate this, it will suffice to take one instance of it, which is for obvious reasons the most common,—the production of internal inflammations by chilling of the skin. The somewhat complex state of things which here occurs I will endeavor to set forth in as clear and brief terms as possible.

The first effect of cold is to depress the tissue-elements of the skin, just as moderate degrees of heat excite or stimulate them. And this depression involves necessarily a lessening of the glandular function—the perspiration, as every one knows, is checked. But the cold acts also upon the involuntary muscular fibres of the skin, causing them to contract, and thus diminishing mechanically the amount of blood flowing among the tissue-elements. Still further, it influences the nerve-filaments dis-

tributed through the skin, whether by a change in their electrical state or by some more specific mode of operation, and throws back upon the ganglionic centres, if I may so speak, an amount of nerve force which must be distributed elsewhere. How far the effect of cold may be to hinder the chemical changes which have been before mentioned as inseparable from the processes of life, can perhaps hardly be determined, and it seems to me that this must be but a secondary and subordinate matter.

Hence the immediate effect of cold upon the skin is depression of the tissue-elements and of the agents of innervation, and diminution of the amount of blood used up by the organ, for such we may most properly call the skin.

But one of the functions of the skin is the keeping down of the temperature of the whole body by evaporation from its surface. This is of course interfered with under the circumstances mentioned, and we have a stimulus which must be felt by some interior organ or organs.

In what way it is determined on which of the internal structures the brunt of the disturbance shall fall, where the innervation, and the repressed blood-current, and the heat, which now fail to be disposed of in the skin, shall come to their inevitable change into other forms of force or of matter, cannot always be clearly made out. Perhaps any organ which is already in a state of full or somewhat excessive activity may be predisposed to become the seat of inflammation. Different persons may perhaps be differently constituted in this respect—so that while in one the liver would readily pass into an inflamed

condition, in another the lungs or the kidneys would be more apt to be so disturbed. Undoubtedly, pre-existing disease in any organ, such as tubercle, or the effect of former inflammatory changes, would make that organ especially liable to the derangement in question.

And this suggests to me that I ought to allude to the causing of inflammation by those diseases which seem more than any other to merit the term *specific*, —tubercle and cancer. It does not seem very difficult to understand why there should very naturally occur, around either a cancerous or a tuberculous deposit, a degree of irritation which may pass into actual inflammation. And yet I must confess that no reason occurs to my mind why the existence of such abnormal growths, even when rapidly increasing, should excite inflammation, otherwise than by a reflex influence through the nerves which are by them rendered the seat of pain. The question is made more difficult by the fact that in so large a proportion of cases, during a great part at least of their course, there is no inflammation around the deposit. It seems clear however that the same laws must apply in this as in the other modes of causation which I have called vital, although they are less easily traced.

I am aware that the sketch which I have now given of the causes of inflammation and their mode of action on the economy is imperfect, and that the views which have been advanced are open to criticism. But my endeavor has been to omit no cardinal or important element of the subject, which is in its very nature a most difficult one to deal with. A

full discussion of it in all its bearings might readily be made to cover all the time allotted to my whole course, and would after all be perhaps productive of no greater practical advantage than that which has been laid before you.

As to the other point, the soundness of the views I have advanced, I can only say that they are those which candid study has commended to my own mind. Nothing short of demonstration can place any statement beyond controversy, and in natural science, or at least in the existing state of pathology, demonstration is impossible. "Even to the present day," says a learned German writer, "it is admitted that there is scarcely any department of human knowledge in which the number of established truths and facts, which no one doubts or attempts to shake, is so small, as in medicine."* And such being the case, one who would discuss subjects like that which has engaged our attention this evening without being prepared to have his views questioned and criticised, must confine himself to the baldest platitudes.

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* Œsterlen, "Medical Logic."

LECTURE V.

TERMINATIONS OF INFLAMMATION—ONLY TWO IN NUMBER—VIS MEDICATRIX NATURÆ—RATIONALE OF RESOLUTION—GANGRENE—DIFFICULTY IN TRACING ITS RATIONALE—PRODUCTS OF INFLAMMATION—STRICTLY SPEAKING BUT TWO—LYMPH AND PUS—LYMPH—ITS SOURCE—CIRCUMSTANCES INFLUENCING ITS CHARACTER—THEORIES AS TO THE RATIONALE OF ITS FORMATION.

We have now, gentlemen, studied all the essential phenomena of a fully developed inflammation, and have taken a survey of the causes of this state and their mode of action. I propose next to call your attention to its terminations, so as to complete the natural history of the disease in its simplest and typical form. We shall then be prepared to inquire into the modifications which it presents, and the incidental consequences which attend it in some cases.

By some authors, it is stated that inflammation may terminate in various ways. Resolution, metastasis, delitescence, induration, softening, adhesion, ulceration, suppuration, and gangrene, are all mentioned as modes of ending of this disease. Other writers, I think more correctly, affirm that there are but two—resolution, or subsidence of the abnormal phenomena, and the death of the affected tissues.

Delitescence, or the sudden disappearance of the local symptoms, and metastasis, or their transfer to some other organ, amount, so far as the affected

part is concerned, to the same thing as resolution, which will presently be examined at length.

Effusion of lymph, induration, softening, adhesion, ulceration and suppuration, are all mere incidents of the inflammatory process, which does not necessarily cease when they occur, but is on the contrary, with regard to some of them at least, essential to their continuance.

The gangrene, mortification, or death of the part, must of course put an end to inflammation in it, and may therefore be properly considered as one of its terminations.

Hence it seems to me to be simple accuracy, and not a hypercritical refinement, to say that there are but two modes in which an inflamed tissue or organ can cease to be so; either by the phenomena of that morbid state disappearing, and the health of the part being in so far restored, or by the death of the part. It must be observed that the statement is not that the inflammation gives way to a condition of absolute health, that the tissue concerned becomes entirely normal, but only that the phenomena of actual inflammation subside.

We have now to inquire into this process of resolution. It is obvious in the first place that a reversal of the conditions which brought about inflammation will cause it to cease—that whatever tends to counteract irritation, such as the removal of stimulus, of the influence of agencies which make the part less sensitive to it, will go to restore the normal state of affairs.

A very common but a very erroneous idea is that which has been combated in another connection,

and which seems to be involved in some degree in the term resolution,—that inflammation is a sort of entity, a something superadded to and seated in the part, and that it melts away like snow in water. The change in nutrition which occurred when inflammation was set up is reversed when it subsides.

If now the phenomena exhibited by an inflamed part, the redness, heat, swelling, pain and disordered function, with or without the formation of that new deposit known as lymph, be considered, and the explanation be recalled which was given of the way in which these symptoms arise, the rationale of resolution will not be very hard to define.

Much has been said in medical writings about the *vis medicatrix naturæ*, and about the natural tendency of parts to return to health. This idea of *nature* has been very much misapprehended and misused. It really means no more than the system of laws under which the atoms of which all material things are composed act and react upon one another. And as I have before urged, these laws are the same, or at least in perfect harmony for organized and for inorganic matter. Only, in organized beings, we have a new condition superadded, and if I may so speak a new code also. It is much the same as when a body of men organize themselves for any purpose. They adopt certain rules and regulations, differing perhaps from the laws of the community in which they live, because their aim is a special one, but not clashing with those laws.

Hence it seems to me that we may positively assert that when a part which has been inflamed returns to health, when, in other words, an inflam-

mation ends in resolution, it is by as pure an obedience to law, and with as little intention on the part of the tissues concerned, as when a chemical compound dissolved in water by heat is let fall again on cooling. The substance, whatever it be, has no tendency to be precipitated, but the conditions under which it was otherwise are done away with. Just in the same manner a piece of India-rubber contracts after being stretched; not because it desires to become shorter, but simply because its normal state has been disturbed, and the force which so disturbed it has ceased to act.

The expression "assisting Nature" is often used, and with a most excellent practical bearing, as indicating the true function of the physician or surgeon. A most admirable work, full of important and valuable doctrines and precepts, has lately been published by Mr. Hilton, the well-known surgeon of Guy's Hospital, London. In glancing over it, my attention was caught by the following sentences:

"In fact, nearly all our best-considered operations are done for the purpose of making it possible to keep the structures at rest, or freeing Nature from the disturbing cause which was exhausting her powers, or making her repeated attempts at repair unavailing. The operation does not cure; it only makes recovery possible, where, without the aid of the hand or head of the surgeon, Nature would have ceased her competition with the results of the injury, or succumbed to the exhausting influence of unmitigated disease. In aneurism—I think I am not in error when I say that aneurism is cured by rest, and not by the surgeon—the surgeon takes care to stop the blood or to moderate its flow; Nature herself actually cures the disease by rest."

I feel constrained, correct as I believe the *bearing* of these statements to be, to enter a protest against

this idea of a gigantic female doctor, to facilitate whose treatment is the sole function of human skill and experience. Nature has no powers, and does not even exist in the sense implied in such expressions. Their incorrectness would be of less consequence if it were not that they are apt to lose the figurative meaning to which they are alone entitled, and being literally interpreted, to color professional thought. Moreover, they go far, when thus used, to form a basis for the absurdity called popular medicine.

The true function of the physician or surgeon is then to assist in the carrying out, in the body, of the laws governing matter in general, and organized matter in particular. His is the intelligence to observe under what circumstances the Creator has ordained that living beings shall find health and comfort, and to devise means by which they shall be kept in or restored to such a condition.

Now, let us ask, what does this *vis medicatrix naturæ* amount to in the resolution of inflammation? It is simply the original healthy status of the part, the law of its formation and endowment with life, interrupted and set aside for a time by some disturbing force, but to conformity with which the part is restored as soon as that disturbing force ceases to act. So long as life lasts, the organ can only fulfil its appointed type as to chemical and physical structure, and in doing this, as I have already urged, it yields a blind obedience to surrounding circumstances. That is, its constituent tissue-elements do so, and it is merely their aggregate.

I am at a loss to conceive where the vis medicatrix naturæ is supposed to reside. It must be, how-

ever, in the individual cells of the tissue, if anywhere, since by no stretch of fancy can we ascribe it to the nerves, or to the vessels, or to the organ itself, as for instance in the case of a muscle or a gland. But each cell lives for itself, utterly unaffected, so long as it is itself not involved, by mechanical, chemical, electrical or other changes of its neighbors. And to my mind, while nothing is easier than to understand this proposition: a living cell, if interrupted in its healthy life by any disturbing agency, and subsequently restored to all the conditions necessary to that healthy life, will resume it under the same law which governed its first bestowal; nothing is more difficult than to imagine a shadowy force which comes forward when disease occurs, and acts as a police to restore order.

To bring down these abstract statements to the concrete, let us take the case of an inflammation of the skin due to the presence of a foreign body. Withdraw that irritating agent, and health is restored—not all at once, for the stimulus applied has induced a change, and a change in processes which are going on, so that it must make itself felt beyond the moment of its occurrence. The same thing happens if the foreign body is thrown off by suppuration; in either case it is gotten rid of, and the irritation is done away with; the tissue-elements are no longer excited either directly or through the reflex influence of their nerves, and the conditions of their healthy life are restored. Hence, simply because they are no longer placed in abnormal circumstances, they begin again to obey the law of their being, for they cannot help it.

Upon precisely similar principles we may explain the return to health of a portion of tissue inflamed by chemical agents—or by those causes which I have called vital. It is not necessary to define the poison of small-pox, for instance, but we know that after a certain time its irritating influence upon the skin subsides. The pustules dry up, and the inflamed area around each one gradually becomes paler and more healthy, until all signs of the disease except the change of form disappear. Here we have a true resolution.

And I believe that if we were to examine in succession all the inflammations to which any part of the body is subject, whether with or without the occurrence of those incidents which I have mentioned,—ulceration, suppuration, etc., we should find that just so far as the exciting cause is done away with, the morbid condition passes off. Just so far, in other words, as the circumstances under which a part is placed are those which favor its healthy life, just so far will it carry on that healthy life. The occurrence of suppuration, of adhesion, of the effusion of lymph, or of any other change in the normal structure, must of necessity prevent, so long as it exists, the return of absolute health; for tissue-elements which are in relation, not with other tissue-elements, but with pus, are by virtue of that very fact in abnormal circumstances, and prevented from living a healthy life. But this is only another way of saying that they are irritated, or that their nutrition is interfered with.

Now it might occur to some of those who hear me, that the tissues sometimes are in contact with

pus, without becoming inflamed; as for example in cases where pus is formed in the upper part of the vagina, and flows down that canal without even reddening it; or in the instance before mentioned, of pus discharged with the urine, without inducing cystitis. These cases are rare; but even when they do occur, they do not invalidate what I have said. For, be it remembered, the pus is here not in absolute contact with living tissue-elements, but only with an epithelial covering whose very office it is to protect the structures lying beneath. The cells composing that epithelium are no longer, except in the deeper layers of it, in process of active nutrition, but are effete, and incapable of undergoing inflammation.

Let me adduce one other instance, in which resolution occurs with an apparent continuance of the cause of inflammation. It is that of the encysting of balls within the substance of the tissues. For reasons which it is unnecessary for me to discuss now, this happy result was formerly much more frequent in gunshot wounds than it is at the present day. But the point I wish to urge is, that in these cases the mass of lead at first gave rise to irritation and inflammation. Lymph, according to laws to be hereafter examined, was effused around it. This new substance was therefore interposed between the foreign body and the neighboring tissue-elements. It is a matter of everyday observation that lead is but slightly irritating to the living structures, perhaps less so than any other inorganic material; the lymph would adapt itself exactly to the smooth surface of the mass, and was developed into a lowly-

organized and not very sensitive tissue, which outwardly was in relation with the cells of the affected part. Here then were circumstances as nearly as possible analogous to those of the normal state; and as soon as they were established, the irritation ceasing, the process of nutrition resumed its healthy character, and resolution was accomplished.

The resolution of an inflammation may take place very rapidly, or it may not be completed for a very long time. It can perhaps hardly be said to be entire until even the abnormal irritability which is so apt to be left in the part has subsided. This may remain even after the swelling has ceased to be perceptible, and the heat and pain have passed away. Under such circumstances, it will be evident that although the part may as a general thing be fulfilling its function normally, it will still be readily disturbed, and the inflammatory state reproduced.

I think however that a distinction may be drawn between this irritability, and another phenomenon which is always seen for a long time in parts which have been inflamed, viz.: the readiness with which the vessels become turgid upon the occurrence of congestion in the neighboring parts. This is merely due to the change in relation between the tissues and the walls of the vessels. A greatly increased afflux of blood having at one time taken place, the channels through which it passed were forced open, and kept so for a longer or shorter period. At the same time the tissues were hindered in their nutrition, and perhaps to a certain extent atrophied. Hence, when there is a congestion of the tissues around, the vessels of the formerly inflamed part yield to the

pressure of the current entering them, just as they had yielded to a like current attracted by the tissues, and the phenomenon of redness merely is reproduced. Such is seen to be the case in persons who have lately had varioloid or small-pox, if they blush; the redness being much deeper in the spots where the eruption was than in other portions of the skin. And so also in a healed wound in the hand; if the member be allowed to hang down, so that the blood gravitates into it, the area of the former inflammation will be accurately mapped out by the marked redness which occupies it.

It may be noticed that in either of these cases the redness will be deepest at the points where it was so originally, and will shade off into the hue of the surrounding skin in just the same way—showing, I think, that it is due to the change already alluded to, viz.: to that of relation between the vessels and the neighboring tissue-elements.

When in the course of time the healing of a wound is perfected, and the nutrition of the part restored to a state of absolute health, this phenomenon is no longer observed; the vessels and the tissue-elements have acquired their original relation, and are no more affected by changes in the blood-current than they were before inflammation had taken place.

Perhaps I need scarcely say that the resolution of chronic inflammation is altogether analogous to that of the acute. It leaves behind it the same liability to congestion, in a more marked degree, indeed, because the habit becomes more confirmed; or, to speak more correctly, the change of relation be-

tween the vessels and the tissues is more persistently established.

Along with the return to the healthy condition of the part, which is implied in the term resolution, there is also, of course, a resumption of the normal relation of the tissues concerned to the rest of the body. The due interchange of nutriment and effete substances begins again between those tissues and the blood. And thus, be the extent of the disease large or small, whatever secondary disturbance of the economy may have ensued upon it is done away with.

The fact must not be overlooked, however, that in the course of an inflammation there may be material changes in the part, which remain after the immediate phenomena of the disease itself have subsided. Thus, to take a very familiar instance, a joint which has been inflamed is very apt to be stiffened, perhaps permanently, by the adhesions which have taken place in and around it. Here there may be complete resolution of the inflammation, and yet the part cannot be said to have regained absolute health. In the case of medical inflammations I believe we may add that there sometimes is palpable, or at least appreciable abnormity of relation to the rest of the body even after resolution has occurred, as for example in the case of the lung, spleen, or liver.

According to the views now presented, then, the disease inflammation terminates by resolution whenever its symptoms subside, leaving nutrition as nearly healthy as possible; although the part may have become the seat of material changes, the cor-

rection of which requires time, or which may even be permanent.

Before leaving this subject, let me call your attention to the fact that in an inflamed part resolution and suppuration may take place at one and the same time. This, in a case where the area occupied by the disorder is extensive, may be readily observed; it happens, I think, in almost all cases in which pus is formed. For when the central portions of the inflamed part are undergoing suppuration, the area of redness, swelling and heat becomes more limited, simply by the occurrence of resolution in its periphery. A very marked example of this is found in the case of boils and carbuncles, which are apt to be surrounded by a good deal of redness and swelling, but which, as soon as the process of suppuration fairly begins, become in appearance much smaller, owing to the subsidence of the phenomena about their outer margins—and this subsidence is nothing more or less than resolution.

The other termination mentioned as possible for inflammation was gangrene, or the death of the part. It is more difficult of investigation than the other and more favorable one, for reasons which will readily suggest themselves. Let us however try to obtain some light as to the mode of its occurrence. The question before us, then, is, under what circumstances do inflamed tissues die?

When any portion of the body ceases to live, it must obviously be by reason of some interference with the essentials of its nutrition. And these essentials are, in the higher animals, proper nour-

ishment, and a due supply of it, a proper state of the part, and a certain influence of the nervous system. In other words, the relation between the blood and the tissues must be of a certain kind, and subjected to a certain degree and mode of innervation, in order to healthy life. Should either of these conditions be absolutely wanting, nutrition must fail—and death must inevitably ensue.

Now the causes of inflammation, as I have described them, were either mechanical, chemical or vital.

It is easy to see how by mechanical causes the death of a part may be brought about. The crushing or tearing of tissue which takes place, for instance, in a railroad injury or a gunshot wound, must so change their structure as to render them incapable of maintaining their life.

And so also when chemical agents disturb the composition of the cells, by abstracting atoms from them or by breaking up the combinations of those atoms, the alteration thus produced may be so radical and complete as to place the keeping up of the processes in which life consists out of the question.

In both these cases we have in the cause of the inflammation a cause also of death to a portion of the tissue, as was shown on a former occasion. And the same may be said of some of the vital causes of the disease—they act as irritants, and they kill certain portions of the tissue concerned.

There are three forms of relation which may exist between inflammation and gangrene, as observed in practice. I say "may exist," because in some cases it is doubtful which of the three obtains.

Thus we may imagine the same cause, not mechanical or chemical, but vital, to induce at once the death of a portion of tissue and the inflammation of that which surrounds it; so that the two states would be simultaneous, parallel, and not in order of sequence.

Or, the starting-point may be the death of a certain congeries of cells, which act as foreign bodies, or at least no longer maintain their normal relation with the neighboring tissue-elements; and hence, as has before been explained, the conditions of healthy nutrition are interfered with, and inflammation is set up.

Thirdly, there may be so violent an inflammation excited in a part, or to speak more accurately there may be so wide a departure from health in this direction, that the tissues die in consequence of it.

To take the familiar instance which I have already used, it is often difficult to say which of these explanations should be given in a case of carbuncle. Here we see first an area of inflammation, the central portion of which is evidently deeper and higher in degree than the rest. Now more blood is passing through the tissues which constitute that area than they would normally contain. But it is evident that this increased amount of nutritive material is not taken advantage of by the part, for after a time there is a total failure to live, an actual death, at the very point where the greatest amount of that material is collected. If all the other conditions were maintained in proportion to the augmented supply of blood, the tissue, instead of dying, would grow. Hence, for some reason or other, the due

interchange of nutritive and effete substances between the blood and the tissue-elements does not take place. If we look upon this whole process as the result of a constitutional disorder, as it no doubt often is, it would be in accordance with the pathological views of many surgeons to ascribe the death of the central portion of tissue and the inflammation of that surrounding it to the same localized poison. Or, we may say, and sometimes with apparent reason, the course of the disease is, that a portion of the subcutaneous areolar tissue dies from such a localized poison, and then the surrounding structures become inflamed just as they would have done if the death or necrosis had been due to mechanical violence. Again, it often seems as if the first phenomenon was an intense degree of inflammation, ending in the death of the central portion of the affected tissue, simply as a result. As a general thing, in the choice between these explanations the surgeon will be influenced in each case by the degree of certainty with which any local cause can be designated. If no such cause appear, the view will seem plausible that some general poison, localized in a way which cannot be clearly defined, lies at the root of the trouble.

What has now been said will suffice to show the main difficulty in the way of tracing in any individual case the relation between the inflammation of a part and its death. It is not often that an opportunity offers itself of observing a pure and simple inflammation which apparently runs on into a condition of gangrene. I am inclined to believe that such a thing is impossible, on grounds to be presently stated.

But, on the view that inflammation is a disorder of nutrition, and that this latter process is by it rendered less active and energetic, we may assume that the more violent the former, or in other words the wider the departure from the healthy state, the greater will be the resulting weakness, and the defect of nutrition therein involved. Moreover, we know that the relations of the several tissue-elements of a part which is inflamed to their sources of supply are interfered with—and therefore that they are not only rendered less able to avail themselves of what they have, but the quantity of nourishment furnished them is inadequate.

And we know that the longer this state of things lasts, the less capable is it of being corrected. There must be a steady and progressive loss of power to carry on the life processes, while oxidation is going on, and chemical combustion taking place even more rapidly than in health.

Hence it needs but a keeping up of the disorder, whether by the continued action of the cause, or by its original severity, or by some failure of the powers of the system at large, to wear out the part, as it were, and thus cause its death. I do not know that any closer analysis of the connection between the inflammation of a part and its death can be arrived at. But I think that whenever such a result occurs, it is owing either to the original cause of the trouble, or to some constitutional defect. Perhaps it may be said that gangrene never takes place except from one or the other of these circumstances—in other words, that when inflammation terminates thus, it is always through conditions external to itself. A

very rude and imperfect parallel, but one which will in some degree illustrate the point, may be found in the supposition of a horse compelled to run until he falls. He is obliged to do more than his strength is equal to. For a time he responds to the stimulus of the lash, but at last his powers fail. And be it observed, no horse would ever run himself to exhaustion in this way; he can do so only under the pressure of stimulation. So it is also with the tissues.

An illustration of this principle may be found in muscular contraction. It is not possible for a muscle to rupture itself, by its own force. When this seems to occur, it is by an excessive influence derived from without. Thus, when the rectus abdominis is torn across, as has happened in a number of instances on record, it is not by its own contraction, but by the power of other muscles which are thrown into violent action, so as to bring a great strain upon it. When other muscles are ruptured, as is sometimes the case in tetanus, it is because they are in a state of excessive spasm from the disease of the nervous system.

And just as it is impossible for simple muscular contraction to be a cause of rupture of that tissue, so I think it is impossible for any tissue to carry the excitement of its nutritive function beyond a certain point unless under the influence of some excessive stimulus from without, or which is the same thing in substance, unless there is a disproportion between the degree of stimulus brought to bear upon it and the provision made for the repair of its waste.

I have now discussed the modes of termination of

inflammation which seem to me to be legitimately so called; taking the ground that this morbid state can come to an end in either one of two ways; first, by the subsidence of the symptoms, and so far by the return of health, or, secondly, by the loss of life. The former event may be due either to the cessation of the agency which gives rise to the disease, or to its counteraction by artificial means; the latter either to the overwhelming stimulation of the part by the cause of the trouble, or to the want of power to carry on the processes beyond a certain point. And this want of power may be ascribed sometimes to the part itself, sometimes to the system at large.

Before leaving this subject, I think it but right to say that there is a certain apparent propriety in speaking of ulceration and suppuration as terminations of inflammation, and indeed I am willing to admit that in one limited sense such an expression is absolutely correct. For, paradoxical as it may at first seem, this does not involve any weakening of the position before taken.

When a part, as for instance a portion of skin and the areolar tissue underlying it, becomes inflamed, we have the phenomena so often referred to,—redness and heat, swelling and pain, with loss of function. And eventually a portion of the tissue may be broken down into pus, either by the formation of an abscess or by ulceration. The exact identity of these two processes will be hereafter shown; but the point now to be made is, that so far as these tissue-elements so disposed of are concerned, the inflammation does truly end in suppuration or in ulceration. But, granting this, it is no less true

that those tissue-elements are, as such, dead—and hence that their inflammation has resulted in their death as parts of the living body. Moreover, it is especially clear in such a case as this, that the phenomena of inflammation do not subside in the neighboring structures, but persist as long as the formation of pus continues, and often much longer.

I am aware that the same may be said of the ordinary process of death or gangrene of an inflamed part,—that in the neighborhood of such a part there is still, and must of necessity be, a continuance of the disorder. But in one case there is what may be called a virtual death only, and so far as the whole theatre of the inflammation is concerned, a subordinate element of that process instituted; while in the other there is an actual death, and in many cases, if not in most, the inflammation which remains in the neighborhood begins from that moment to decline.

We have now, gentlemen, completed the study of the natural history of inflammation, in the simplest form under which it presents itself. We began by considering it as it appears when fully developed, and examined in succession the various phenomena of which it is made up. Next we inquired into the causes by which this morbid state is brought about; and finally, we investigated the modes in which it terminates.

There remains still something to be done, in order that we may have a full view of the disease; we must look at the products to which it gives rise. It has been a matter of much doubt with me, whether it

would not be better, before taking up this subject, to examine into the anatomical peculiarities of the various tissues; but I believe we shall accomplish our purpose more satisfactorily by first turning our attention in a general way to the so-called inflammatory exudations.

You will probably remember that when speaking of the causes of the swelling which forms so constant an element of inflammation, I stated that it might be due to the escape from the blood-vessels either of blood as such, or of the watery portions of it, or of a liquid closely resembling the liquor sanguinis or lymph. And it is a matter of experience as well as observation with almost every one, that in very many cases of inflammation the swelling is in great measure formed, at a somewhat late stage of the disorder especially, of the liquid known as pus.

Of all these exudations, blood, serum, lymph and pus, the last two only can be looked upon as properly speaking products of the inflammatory process. Blood may be effused as a consequence of rupture of the vessels under almost any circumstances, and may give rise to inflammation, but it does not belong to it as a product, even incidentally. And, as in the familiar instance of anasarca, the watery portions of the blood may be mechanically caused to escape through the walls of the vessels, without there being any inflammatory condition in the system at all.

Hence the present inquiry is narrowed down to the formation, in inflamed parts, of lymph and pus.

Concerning the origin of inflammatory lymph, the views of pathologists have varied greatly from time

to time. As to its physical characters, they are not hard to observe. It is a substance presenting different degrees of consistence, from that of an almost clear liquid to that of a semi-solid. In color it is of various shades, from a slightly opalescent, almost colorless hue to a decided yellow. Placed under the microscope, it exhibits equally diverse characters—sometimes it is scarcely distinguishable from blood deprived of its red corpuscles, sometimes it is quite strongly fibrillated.

A property always more or less marked in this substance is its tendency to coagulate—so that it early acquired the name of "coagulable lymph." An expression very common among writers on pathology is the "throwing out of coagulable lymph." The correctness of this phrase will be presently discussed.

Now it was said a few moments ago, that this lymph was scarcely distinguishable in appearance from blood deprived of its red corpuscles. And it will of course occur at once that these two liquids have another property, that of coagulation, in common. It would therefore be very natural to infer that they are the same; that in order to the production of lymph, there should be simply an escape from the vessels, through their walls, of the liquid portion of the blood, with its colorless corpuscles. But to this theory there is one very grave objection, —that it is impossible for a body like one of the colorless corpuscles of the blood to pass through a membrane such as constitutes the capillary walls, without a solution of continuity in the latter. Some other explanation must therefore be sought.

The view which tallies best with all the facts of the case, and the one which accords with the statements advanced and defended in the course of our previous inquiry, is that the development of lymph is effected under the direct influence of the tissue-elements among which it comes into existence. That is, when inflammation occurs, the change in the relations between the blood-vessels and their contents on the one hand and the cells of the part on the other, is such that an escape takes place from the former of certain ingredients, which under the influence of the latter undergo organization into special forms. Besides the general ground of analogy, we have in favor of this mode of stating the case the fact, which will be further developed hereafter, of the marked influence exerted upon the character of lymph by that of the tissues in connection with which it is formed. Especially is this displayed in those cases in which the organization of the inflammatory product is carried on to the formation of tissues, as for example when bone is developed in the neighborhood of bone.

Side by side with this truth must be placed another, viz., that the state of the blood has much to do with the further history of the lymph separated from it. One of the simplest and best modes of obtaining lymph is by means of blisters applied to the skin. Let me quote Mr. Paget's account of a series of experiments made by him in the investigation of this subject:

"To test this matter," says he, "I examined carefully the materials exuded in blisters, raised by cantharides plasters, applied to the skin in thirty patients in St. Bartholomew's Hospital. Doubtless, among the results thus obtained, there

might be some diversities depending on the time and severity of the stimulus applied; still, it seemed a fair test of the question in view, and the general result proved it to be so. For, although the differences in the general aspects of these materials were slight, yet there were great differences in the microscopic characters; and these differences so far corresponded with the nature of the disease, or of the patient's general health, that at last I could generally guess accurately, from an examination of the fluid in the blister, what was the general character of the disease with which the patient suffered. Thus, in cases of purely local disease, in patients otherwise sound, the lymph thus obtained formed an almost unmixed coagulum, in which, when the fluid was pressed out, the fibrine was firm, elastic, and apparently filamentous. In cases at the opposite end of the scale, such as those of advanced phthisis, a minimum of fibrine was concealed by the crowds of corpuscles imbedded in it. Between these were numerous intermediate conditions which it is not necessary now to particularize. It may suffice to say that, after some practice, one might form a fair opinion of the degree in which a patient was cachectic, and of the degree in which an inflammation in him would tend to the adhesive or the suppurative character, by these exudations. The highest health is marked by an exudation containing the most perfect and unmixed fibrine; the lowest, by the formation of the most abundant corpuscles, and their nearest approach, even in their early state, to the characters of pus-cells. The degrees of deviation from general health are marked, either by increasing abundance of the corpuscles, their gradual predominance over the fibrine, and their gradual approach to the characters of pus-cells; or else, by the gradual deterioration of fibrine, in which, from being tough, elastic, clear, uniform, and of filamentous appearance or filamentous structure, it becomes less and less filamentous, softer, more paste-like, turbid, nebulous, dotted, and mingled with minute oil-molecules."*

Mr. Paget goes on to say that so far as observation has gone, the analogy or parallelism thus drawn between the condition of the system and the quality

* Lectures on Surgical Pathology, p. 220 (Am. ed., 1854).

of the lymph exuded in blisters holds good also with regard to the clots found in the heart after death. And this is what would have been expected from what we know of the relation between the state of the blood and that of the general health.

Another circumstance, which must materially influence the physical characters of the lymph formed in any case of inflammation, is the amount of serum which, whether by mechanical agencies or otherwise, is present along with it. This, as was before remarked when the effusion of lymph was incidentally mentioned in connection with the phenomenon of swelling, may be looked upon as a mere dilution. Obviously, when the quantity of serum is large, the solid constituents, the corpuscles and fibrillated elements, must be relatively diminished. Such is apt to be the case in persons of weakly constitution and relaxed tissues. But so long as it exists, it doubtless prevents the permanent organization of the new material, as indeed would â priori have been supposed.

Hence we have seen that when, in any case of inflammation, the so-called *effusion* takes place, this may be either of a liquid corresponding to the serum of the blood,—water holding some albumen and certain salts in solution; or of a substance nearly analogous to the blood itself, but destitute of red corpuscles; or of a mixture of these two. And we notice also that in this lymph, whether diluted or not with serum (but more markedly the less the quantity of serum), there is a tendency to the fibrillation of certain of its constituent elements. The circumstances determining the character, in any case, of the sub-

stance effused, are found to be: the state of the system at large, acting probably through its influence upon the general blood-mass; the normal structure of the part concerned; and the degree, as well as the nature, of the disturbing agency.

In robust persons, and in parts whose tissues are compact, the effused material is dense and quickly fibrillated; in weakly patients, or in relaxed and flabby parts, it is a thin liquid, and tends to remain in that state. Of the influence of the anatomical structure of the various tissues, I shall have occasion to speak more particularly hereafter. The effect of the degree and nature of the disturbing cause upon the character of this substance, is somewhat difficult to appreciate; but we know that in violent inflammations the lymph deposited is more apt to be rich in solidifying ingredients; and that in eczema, for example, the contrary is the case.

So far our attention has been directed only to matters of actual observation; we have not yet inquired into the rationale of the production of lymph. It is concerning this that the views and statements of pathologists have varied most widely. The idea which has most generally prevailed is that either from mere mechanical causes, or by virtue of an unexplained power residing in the vessels, there was a separation from the blood, a filtering through the capillary walls, of portions of that liquid; much as a wholesale desertion might take place from a military force on their march through an enemy's country. And from this very vague idea as a starting-point, equally vague explanations have been given as to the further fate of the material thus as it were

let loose among the tissue-elements. Coagulable lymph, being thrown out, coagulated; just as blood drawn from the vessels would do so.

But any rational theory of this occurrence must account in the first place for the passage of the atoms of lymph through the capillary walls, and secondly for the change which takes place in it after it has so escaped. For most certainly the colorless corpuscles cannot pass through the walls of the vessels, and if they could, the number of the corpuscles in any specimen of inflammatory lymph is far greater than it should be if they were so derived.

The substance which is formed has been thought by most pathologists (or at least such would be the inference from the expressions they use) to have a certain indwelling power of taking on organization. And for this idea there is some foundation, since when serous effusion takes place, it merely infiltrates the tissues; when lymph is deposited, it assumes definite forms, and may pass into a permanent relation with the neighboring structures. It may indeed undergo development into definite structure, as when the irritation of a foreign body in contact with a bone induces exostosis; here it is beyond question that the source of the newly-formed bone is the lymph thrown out by reason of the inflammatory condition of the original tissue.

But I think it can hardly need any extended argument to show that in any such case the successive steps of the process are properly so called. In other words, it is not that the formation of bone is an object aimed at from the beginning,—that in order to

this a substance is separated from the blood within the vessels, which substance takes various preliminary degrees, if we may so speak, until it at length graduates as bone; but that, under certain influences, brought to bear one after another, the plastic material undergoes change after change, blindly and passively.

Upon this view, it is evident, we may also exclude as special agents in the process the nerves and the vessels of the part. Necessary as these may be to its completion, they are so only as in the ordinary carrying on of nutrition—the vessels as channels through which the material requisite for organization flows to the spot, the nerves as conveying that influence, however explained, under which the developmental changes go on.

It remains to be seen whether from the results of our past inquiry into the process of normal nutrition, and into the modifications of it which constitute inflammation, we can derive anything like a satisfactory theory as to the origin and development of lymph—and with this subject I hope to deal in my next lecture.

LECTURE VI.

ORIGIN OF LYMPH—THEORY OF BLASTEMA—SCHWANN'S VIEWS—VIRCHOW'S VIEWS—CELLS ALWAYS DERIVED FROM CELLS—DEVELOPMENT OF NEW CELLS BY DIVISION OF PARENT-CELL—ENDOGENOUS CELL-GROWTH—LYMPH DERIVED FROM THE CELLS OF EPITHELIUM OR OF CONNECTIVE TISSUE—ITS PURPOSE NOT ESSENTIALLY PROTECTIVE—DEVELOPMENT OF LYMPH—USUALLY INTO CONNECTIVE TISSUE—OTHER FORMS—HOW INFLUENCED—DEVELOPMENT OF LYMPH INTO HETEROLOGOUS ELEMENTS—FORMATION OF NEW VESSELS—HUNTER'S VIEW—MODERN THEORIES.

At the conclusion of my last lecture, gentlemen, you will remember that I was about to take up the subject of the origin and development of inflammatory lymph, with a view to its satisfactory explanation, if this were possible.

And first, of its origin. The various tissues, according to the closeness of their normal relation with blood-vessels, receive whatever nutritive material they need, and this may be stated as the main or central function of their constituent elements. And as I have more than once had occasion to remark, this life of each cell, strictly so called, is most intimately bound up with its duty, the latter flowing inevitably from the former. Derange either, and the other must be disturbed. Hence, whenever any irritation is applied to any living cell, the first effect of it is to augment the amount of nourishment taken up by that cell, and the activity with which it dis-

charges its office. This would be true of any one cell, if we could imagine one alone to be so irritated; but in the actual state of things, a congeries of cells must always share in any disturbance of the kind.

And thus, according to the views advanced in the previous lectures of this course, more blood is attracted by the cells so influenced, and the vessels become turgid; redness, and an increase in the size of the part, result. The interchange of chemical elements,—the combustion, involved in nutrition, becomes more rapid, and hence there is a rise of temperature; and pain is caused by this, as well as by the pressure upon the nerve-filaments, the intrinsic change in them, and in some cases by the original cause of all the mischief. And the affected cells must cease to discharge their office in the economy normally.

Now if the stimulus is continued, the cells will go on attracting blood. But they can take into themselves no more nutritive material. Here then is a substance all ready to enter into the composition of living cells, supplied according to a demand made by the tissues, and supplied in greater quantity than they can use for their own growth.

According to the views entertained from the time of the origination of the cell-theory until very recently, this superabundant material was effused into the interstices between the tissue-elements of the affected parts, and then received the name of *blastema*, from a Greek word signifying to bud or germinate. Within this formless material there was sup-

posed then to begin a process of aggregation of atoms here and there, forming nuclei, which attracted around them still other atoms, and these again others, until the cell-contents and the cell-wall were formed around the nucleus as a starting-point.

Schwann, who may be regarded as having been the father of the cell-theory, held this view. He says:

"The following admits of universal application to the formation of cells; there is, in the first instance, a structureless substance present, which is sometimes quite fluid, at others more or less gelatinous. This substance possesses within itself, in a greater or less measure according to its chemical qualities and the degree of its vitality, a capacity to occasion the production of cells. When this takes place the nucleus usually appears to be formed first, and then the cell around it. The formation of cells bears the same relation to organic nature that crystallization does to inorganic. The cell, when once formed, continues to grow by its own individual powers, but is at the same time directed by the influence of the entire organism, in such manner as the design of the whole requires."*

Some trifling modifications of this theory were from time to time suggested, but it was as a general thing accepted in very nearly its original form until the recent researches of Virchow, and the publication of the doctrines based upon them. According to this author there is no such thing as an exudation of formless substance, within which cells are developed by a sort of instinct; but every cell must be legitimately descended from some other pre-existing cell. In contrast with the quotation just given from Schwann, let me make an extract from the "Cellular Pathology":

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* Schwann and Schleiden's Researches (Syd. Soc.'s Transl.).

"At the present time, neither fibres, nor globules, nor elementary granules, can be looked upon as histological starting-points. As long as living elements were thought to be produced out of substances previously destitute of shape, such as formative fluids, or matters (*plastic matter, blastema, cyto-blastema*), any one of the above views could of course be entertained, but it is in this very particular that the revolution which the last few years have brought with them has been the most marked. Even in pathology we can now go so far as to assume, as a general principle, *that no development of any kind begins* de novo; *and consequently we may reject the theory of equivocal* [spontaneous] *generation as well in the history of the development of individual parts as in that of entire organisms.* And just as we can not admit that a tænia can arise out of saburral mucus, or that out of the residue of the decomposition of animal or vegetable matter an infusorial animalcule, a fungus, or an alga, can be formed,—we cannot concede either in physiological or pathological histology, that a new cell can be built up out of any non-cellular substance. Where a cell arises, there a cell must have previously existed, just as an animal can spring only from an animal, a plant from a plant. In this manner, although there are still parts of the body where absolute demonstration has not yet been afforded, the principle is nevertheless established, that in the whole series of living beings, whether they be entire plants or animal organisms, or essential constituents of the same, an eternal law of *continuous development* holds good."

The same doctrine is elsewhere further developed by Prof. Virchow in relation to tuberculous and typhous deposits, as well as to other pathological new-formations.

Now when a simple incised wound is received, on the finger for example, we presently see a somewhat glutinous straw-colored liquid poured out between its edges. This liquid, taken off on a glass plate and put under the microscope, shows the ordinary corpuscles known as lymph-corpuscles, floating in a

clear menstruum like the liquor sanguinis. Whence do these bodies come? That they must owe their origin directly to the tissue-elements from among which the liquid escapes, seems beyond a doubt. The learned author just quoted would ascribe them to the areolar or connective tissue; he says:

"We may therefore, with trifling restrictions, *substitute for the plastic lymph,—the blastema of the earlier writers and the exudation of the later,—connective tissue with its equivalents as the common stock of germs of the body*, and directly trace to it, as their general source, the development of new-formations."

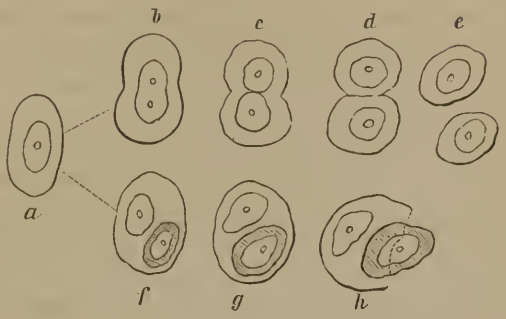
There are two modes in which an existing cell may be imagined to give rise to the formation of new cells, viz.: first by division, just as the cell which constitutes the ovum is cleft or subdivided into millions of smaller cells, which themselves grow, divide, and become the parents of others, and so on, as long as the new formation of tissue-elements lasts. Secondly, by the development within existing cells of others, which by the bursting of the former, or perhaps by the absorption of its wall, are left free to grow and take their place as individuals in the economy.

A diagram will render these two processes clearer to those unfamiliar with the subject. (Fig. 1.) At *a* is seen a cell of the typical form; at *b* it is seen beginning to be constricted in the middle, the nucleus undergoing the same change; *c* and *d* represent the further steps of the process, and at *e* the two resultant cells are seen completed.

The other method of cell-generation is seen at *f*, carried on further at *g*, and the mother-cell at *h*,

bursting, allows its offspring to escape as a fully-formed new cell.

Fig. 1.



According to what we see in the study of mere anatomy, whether of healthy or of morbid tissues, the former of these methods—that by division—is by far the more common of the two. A very striking example of it is found in articular cartilage, where a dozen or more cells may be seen arranged just as they were formed by the cleavage and separa-

Fig. 2.

(From Leidy.)

tion of the primary cell. (See Fig. 2.) And no doubt in epithelium many if not all of the elongated and

binucleated cells which we see would have gone on to division into two or more new cells, had their life continued. It is perhaps scarcely necessary for me to mention the very frequent occurrence, in rapidly-growing cancers, of cells with two or more nuclei, and of shapes indicating a tendency to divisional multiplication.

As to the other mode of origin,—the formation of cells within cells,—it is asserted by authors, Kölliker, Leidy and others, that it occurs sometimes in cartilage, and is seen also in the supra-renal capsules and in the pituitary body. Paget speaks of it as having been observed by him in some cases of cancer. I am not so presumptuous as to suggest any doubts as to the correctness of statements so authoritative; but I may be allowed to say that it has never happened to me to be able to convince myself, in the cases where such a process of endogenous cell-formation seemed to be going on, that the appearance was not due to an optical illusion.

But this is not a matter which belongs to our present inquiry—for it is not probable that any one would assert that the cells observed in inflammatory lymph were of endogenous formation. The question here lies between the development of cells by spontaneous generation in a structureless substance poured out from the vessels, and their origin in a division or proliferation of the elements of the neighboring tissues. Now, as will further appear when we come to consider the anatomical relations of the tissues to one another, there is no conceivable situation in which lymph is found as an inflammatory product, where there is not in pre-existence

either epithelium or connective tissue. And according to the views of some recent histologists, the alliance between these two is closer than has been generally thought.

But in epithelium we have elements which are of extremely rapid development, and which, moreover, are low in the scale of vitality, having almost everywhere an office in great degree protective. And in cases of irritation, of the skin for example, which scarcely amount to inflammation, we are familiar with the formation of large quantities of epithelium in a short space of time.

In connective tissue we have likewise forms of low grade, developed quickly, and, which is a step farther, analogous to inflammatory lymph in its final state.

If then there is so little evidence for the idea of a spontaneous generation of organic forms in the matter derived from the blood passing through an inflamed part, as to warrant its rejection, the view which has been hinted at, that those forms owe their origin to the division or proliferation of already existing connective tissue-cells or epithelial cells, seems to possess some claims to favor as a substitute for it. To my own mind, the arguments for the latter theory are, in the present state of the subject, conclusive.

It must however be admitted, I think, that the fibrillation which is so familiar as an accompaniment of cell-formation in inflammatory lymph is not in any way accounted for in the explanation just given. Perhaps this point may be cleared up by further observation, and the fact of its being still obscure does

not seem to affect the force of the reasoning applied to the rest of the process. At all events, I am not at present prepared to offer any additional theory in regard to it.

The formation of inflammatory lymph, then, may be considered as the work of the tissues, and this not merely in the way of an influence exerted upon a substance wholly structureless, but by actual contribution of material. Our first acquaintance with lymph is after the arising of the new elements in it. We do not know it in an amorphous state, but we do know that if exuded through the capillary walls it must be in such a state. Very probably there may be such an exudation, constituting perhaps the liquid in which the newly formed cells are bathed; and it may not be too bold to suppose that the overplus of nutritive material attracted to the part by the irritated cells is thus thrown out into the interstices, as it were, of the developing tissue-elements. But this is manifestly a different thing from the coagulable lymph, poured out and at once assuming a process of independent and spontaneous cell-generation, which has so long been undoubtedly accepted by pathologists.

Another idea which has been received without question by almost all who have theorized on this subject, is that of the protective or beneficial purpose of the effusion of lymph. We are told that this substance erects a barrier against the extension of disease; that it binds together parts which have been accidentally separated, and covers up such as would otherwise be rubbed when in an already inflamed and tender state.

But this rule must work both ways; and if it be a beneficent provision of nature that lymph should be effused in one place so as to do good, it must on the other hand be either a malicious contrivance or a careless mistake that a like effusion elsewhere should do so much harm, as by the closing of a duct, or the stiffening of a tendon in its sheath.

The truth is, that in either case the effect is incidental. It is a part of the disease inflammation, just as the protection from smallpox which follows vaccinia is a part of that disease. It so happens in one instance that the lymph organized serves a useful purpose; but in another it so happens that it does a good deal of harm. Perhaps it may be asserted that there is no such thing known to physical science as unmitigated evil.

And here we may consider the relation of the effusion of lymph to the repair of injuries. The best discussion of this subject with which I am acquainted may be found in Paget's "Surgical Pathology." By this author it is clearly shown that injuries may be completely repaired without the formation of lymph at all—although this occurs in most cases. Perhaps nearly every one has met with instances of this immediate union. Some years ago it happened to me in my own person much to my surprise. I cut my finger quite severely with a sharp knife; and being busily engaged, I merely wrapped a handkerchief firmly about the part for some hours; upon removing it the cut was completely and permanently closed. Another and still more striking instance, I think, was exhibited to the College of Physicians during the past year by Dr.

Hewson. It was a specimen from a case in which he performed Pirogoff's amputation, sawing off the lower end of the tibia and the anterior part of the os calcis, and bringing the two surfaces of bone into apposition. They are now perfectly united, without any sign of intermediate substance.

From these cases and similar ones it can only be inferred that the effusion of lymph is not essential to the healing of injuries. Generally this occurs; not as a means of repair, but as a mere incidental result of inflammation. And this is the only point I wish to urge in regard to it at present. We find that after injuries, inflammation takes place, with a formation of lymph; and we find that in very many cases of inflammation not preceded by any definable injury, but apparently arising spontaneously, the same deposit occurs. We find, moreover, that in one case of inflammation, as for instance in the pleura, the lymph serves a useful purpose, as in limiting the extent of the disease; while in another, as in the urethra, in gonorrhœa, it gives rise to intense suffering, by binding down tissues which should be distensible when the organ becomes turgid with blood.

Putting all these facts together, it seems clear that the true light in which this deposition of lymph should be regarded is as a result of the formative irritation exerted upon the tissues of the part. It is one of the processes which the Creator has ordained to take place under certain circumstances, just as he has established the law of gravitation, or the laws under which water freezes. And just as in these two cases, it is according to outside conditions

in every instance whether the working of the law shall seem to be beneficial or not. In general, it is true, all the laws governing matter tend to the advantage of living beings; but none of them invariably do so.

We have further to consider the development of the lymph originated by the tissues of inflamed parts.

In the great majority of cases, the form ultimately assumed by the adventitious deposit is that of connective tissue. Sometimes, however, the process goes further, and new developments of structures allied to this substance take place. The subject opened up by these statements is one of great extent and importance, involving several as yet obscure points in pathology. I do not feel qualified to do more at present than to indicate its scope and bearings.

Allusion has already been made to the cellular character of the ovum, and to the mode in which, by its division and subdivision, vast numbers of cells are generated. From this starting-point proceeds the development of all the various tissues which enter into the organism.

In the course of this development connective tissue, as is well known, occupies an important place as a transition-form through which several other tissues pass before they reach their permanent condition. Thus there is a time when the masses which are ultimately to constitute muscles, voluntary or involuntary, present no difference from connective tissue; and out of the same or similar masses all the flat bones are formed.

Now when we consider the development of in-

flammatory lymph, the antecedent conditions are obviously very different from those in the case just mentioned. There must be in the latter a certain forecast programme according to which every portion of the organism arises; in the former there is simply an accidental production, abnormal in all its relations, and determined as to its issue by circumstances outside of itself. Hence in the case of the inflammatory deposit, we never know what to predict as to its ultimate form; sometimes it is connective tissue merely, sometimes bone, sometimes a heterologous or cancerous substance.

Mr. Paget quotes Mr. Adams as describing, in his work on "Chronic Rheumatic Arthritis," the supposed development of lymph into articular cartilage; he also says that Virchow "has twice seen nerve-fibres in adhesions. In one case, two fine nerve-fibres passed through an adhesion of the pleura; in the other, a single fibre extended into, but not through, an adhesion between the liver and diaphragm."

Förster, in his "Handbuch der Pathologie," speaks as follows of these cases:

"This author (Virchow) observed the presence of nerve-fibres in adhesions; in one case (a pleuritic adhesion) two, running close together, had the characters of the finest double-contoured nerve-fibres; in the other (an adhesion between the diaphragm and the liver) a single nerve-fibre passed along with the connective tissue, divided, and ended in a point. Both adhesions were at least $1\frac{1}{2}''$ long and ribbon-like.

"It is very evident to me, that these nerve-fibres were not of new formation, but should be looked upon as branches of the normal nerves of the serous membrane, which were carried along with the growing fibrous mass."

Mr. Paget inclines to think that lymph may be developed into epithelium. He speaks of it as covering the surfaces of well-formed adhesions; and then says:

"I know of no observations proving whether the epithelial cells are developed directly from the lymph, or are a later construction from materials derived from the blood of the adhesion's vessels; but it is not rare to find, in inflammation of serous membranes, recent lymph cells presenting many characters indicative of development towards epithelium; flattened and enlarged, and having circular or oval clear nucleoli."

With the one exception of the nerve-fibres said to have been seen by that experienced and accurate observer Virchow, it would appear that the tissues into which inflammatory lymph becomes transformed are all mechanical in function and low in the scale of organization. Connective and elastic tissue, cartilage, bone, epithelium,—all these are of this description. In regard to epithelium it must be remembered that the recent researches of physiological anatomists have tended to place it in a much closer histological relation with the obviously mechanical tissues, and especially with the connective, than was formerly supposed. Nor is this idea rendered improbable by the function which epithelium very generally fulfils, in the way of protection to underlying structures.

As to the mode in which the development of lymph is influenced by the already existing tissues in its neighborhood, I have nothing to offer. To say that it is by a catalytic force, inducing the cells simply to imitate those near which it finds itself, is only to put the fact in another form, and not to ex-

plain it. Moreover, we sometimes meet with cases in which even this condition is wanting, as for example when bony or bone-like deposits take place in the subserous tissue of the pulmonary pleura, in the muscular structure of the heart-walls, or in the dura mater.

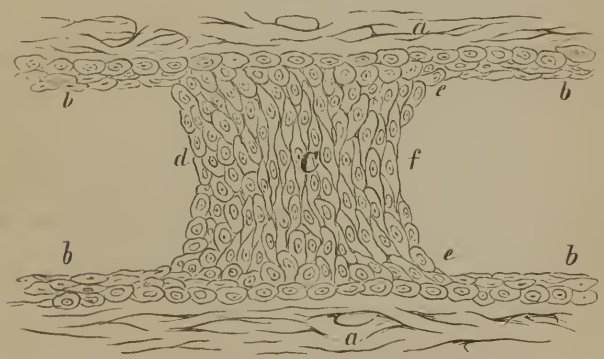
It should be noted that in every instance this development is confined to the production of simple tissues; it never goes as far as the forming of organs. We cannot imagine such a thing as the construction of a supplementary gland, of a supernumerary finger, or of a muscle, in this way. I have quoted Paget as describing the construction of epithelium, or a very good substitute for it, upon the surface of cicatrices, as well as upon that of the masses of lymph which so often form adhesions between the opposed layers of serous linings of cavities. But, in the first place, it was also stated that the recent researches of German histologists have tended to establish a much more intimate relation between the cells of epithelium and those of connective tissue than was formerly allowed; and secondly, in every such instance of the formation of an epithelial covering there is traceable a direct contact between the outermost margin of the lymph-elements so transformed and the previously existing epithelial cells normally lining the cavity.

We have therefore a twofold explanation of the mode in which such a transformation may take place. It may either be due simply to the accident of situation, the connective tissue cells on the surface of the cicatrix or of the organizing adhesion assuming secondarily the shape and function of epi-

thelial cells, and not needing to undergo, in so doing, anything like what might be called a radical change. Or, just as inflammatory lymph in the neighborhood of bone may acquire the characters of osseous tissue, the moulding influence of the adjacent epithelium all around the borders of the new deposit may be so exerted as to induce the cells of that deposit, first at its edges and afterwards by successive steps all over its surface, to assume a like type.

The diagram (Fig. 3) will further illustrate these views. *C* is a section of a mass of lymph formed between the two layers of an inflamed serous membrane. At *b*, *b*, *b*, *b* are seen the epithelial cells lining the cavity, by the proliferation of which cells the connective-tissue corpuscles constituting the lymph are formed. At *d* are seen the superficial

Fig. 3.



cells of the adventitious mass, undergoing from the accident of their position a change into the epithe-

lial character. At *e*, *e* are seen the normal epithelial cells advancing so as to form a covering for the adhesion-band, the process being still unaccomplished at *f*. The subserous connective tissue is represented at *a*, *a*.

It must be evident that these two agencies may be at work at the same time, and therefore that the adoption of one does not exclude the other. I do not know that in the present state of our knowledge we can reasonably reject either, although the mode in which an existing tissue influences the character assumed by that which is developed in its neighborhood is so obscure that the whole process may be actually open to some doubt from that circumstance alone.

A more serious question, although perhaps not one of greater practical importance, is in regard to the development of lymph into heterologous or cancerous tissue. Almost invariably, when in any case of malignant disease there is an injury spoken of as the starting-point of the trouble, it was sustained many years before the latter occurred. Thus in a case of mammary cancer which came under my notice within the last week, the patient remembers having sustained a blow at the same point, long ago, from the elbow of a person crowding past her in the market. Now although a malignant tumor may undoubtedly form in many instances without such a history being traceable, yet there are so many cases bearing the other way that the idea of a causal connection seems scarcely to be set aside.

It may be objected, however, that after a mere blow it would hardly be probable that any appre-

ciable quantity of lymph would be deposited, to lurk until some accident, or the law of its organization called it to act the part of a disturber. The answer to this is twofold. In the first place we do not know what amount of lymph there may have been as the result of the primary injury, and particularly in such a region as that of the female breast. Secondly, the case has been already quoted of a man who had sustained a heavy fall upon the buttocks, just before the manifestation of smallpox in his person; and the eruption came out far more copiously there than elsewhere. If we assume the existence of a vice of constitution as the primary condition of the cancerous disease, then a blow or other injury of any part may be readily imagined as producing just the amount of impairment of structure which should render that part liable to become the seat of a local outcropping of the general disorder.

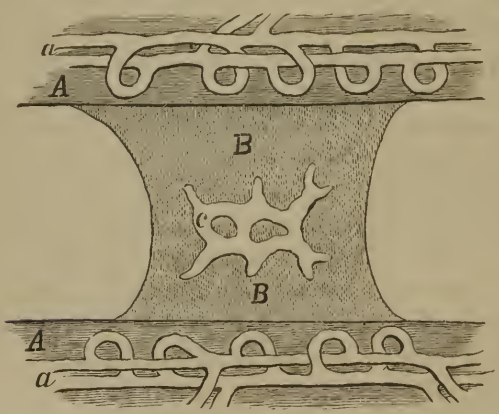
Thus far, in the study of the development of lymph, I have called your attention only to the changes in the structure of the individual tissue-elements of which it is composed, these being so altered as to assume characters nearly or altogether allied to those of connective tissue, of bone, of epithelium, or perhaps of nerve-fibres. And if it be proved in any case that lymph deposited in consequence of inflammation is so changed as to become the basis of a cancerous or malignant growth, this is also, so far as the local disease is concerned, a development of that lymph.

But it is by no means uncommon to observe, as for instance when a mass of inflammatory lymph is

torn off from a serous surface, that vessels are ruptured in so doing; small red points appearing on each of the separated portions. Here is a new feature in the subject; the lymph as thus organized in connection with the surface is vascular, and our inquiry would be incomplete if we left this fact unaccounted for.

Hunter's idea was, that the formation of the vessels and their contained blood in the substance of organizing lymph was effected in the same way as in the embryo—that, of the mass of material poured out or exuded from the neighboring vessels, part became fibro-cellular, while another part took upon itself the form of blood, still another inclosing this

Fig. 4.



blood and acting towards it as the vascular walls do to the blood within them in the normal tissues.

This view may be readily understood from the

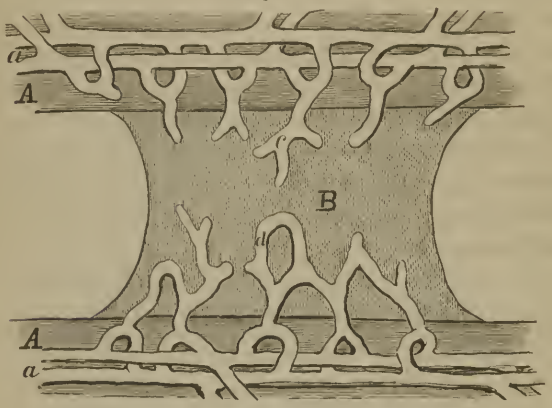
annexed diagram. (Fig. 4.) The mass of lymph deposited between two serous surfaces is seen (*B*) with ramifying vessels (*c*) forming in its central part. *A A* is the serous membrane, *a a* its vessels. We must either suppose that some cells of those which go to make up this mass of lymph assume the characters of blood-cells, while others agree as it were to arrange themselves into the containing vessels, or else that the first-named cells are simply contained in cavities which form between the other cells, which preserve their primal state. Under what influence those blood-cells are developed, how the containing vessels or cavities are originated, does not appear.

And yet there ought to be some such rationale offered, to justify the assumption that this process occurs. The circumstances, be it remembered, are not analogous to those of the ovum, where the new being is undergoing its development,—but the lymph is an accidental and abnormal product. No propelling organ is ever formed, the vessels developed are never anything more than capillaries, passive channels along which the current flows with a force and rapidity determined by causes wholly outside of it. No one has ever seen, either within a serous cavity, or on the surface of the skin or a mucous membrane, a mass of lymph having an independent system of blood-vessels in its central portion, while its periphery was destitute of such supply. And yet, were such a phenomenon possible, it could hardly fail to be observed, in the abundance of cases likely to present it.

The more modern view is that the vessels border-

ing on the lymph send out processes into it, which gradually advance more and more into it, ramify and form anastomoses, and thus establish a capillary

Fig. 5.



circulation. The diagram (Fig. 5) will show what is meant; the letters being the same as in Fig. 4, except that *c* is a vessel shooting out into the mass of lymph, while *d* is a loop formed at a more advanced stage of the vascularization on the other side.

Now the theory I would present is merely a modification of this. Rejecting the idea that the vessels can of themselves send out prolongations or processes, I would suggest that the newly formed cells need blood, and attract it; and that it is the attraction thus exerted, drawing the blood-corpuscles toward the cells, which causes the pouching out of the capillary walls. These walls, thus yielding, may

be fairly supposed to become thinner in so doing. Very possibly they soon give way altogether, and the blood finds a passage in the interstices between the lymph-corpuscles.

The great difficulties inseparable from the study of this subject, and the impossibility of demonstrating the steps of the process, make it especially needful to avoid hasty or positive conclusions. The theory which I have sketched seems to me to agree best with the facts of the case, and perhaps covers the whole ground; but I am by no means prepared to insist upon it. It will be further discussed in my next lecture.

LECTURE VII.

MODE OF DEVELOPMENT OF NEW VESSELS IN INFLAMMATORY LYMPH—OF LYMPHATICS, ETC.—OFFICE OF LYMPH IN THE REPAIR OF INJURIES—ATROPHY OF LYMPH—PUS—PHYSICAL AND CHEMICAL CHARACTERS—MICROSCOPICAL APPEARANCES—MOVEMENTS OBSERVED IN PUS-CORPUSCLES—ORIGIN OF PUS—VIEWS OF DIFFERENT AUTHORS—MODERN VIEW.

You will probably remember, gentlemen, that at the close of my last lecture I was engaged in the discussion of the subject of the development of inflammatory lymph. We had inquired into the different changes through which the cells of that product passed before they reached that state which was to be retained by them as portions of the economy, and had begun to examine into the modes in which the blood-vessels and their contained blood, which are so often found in the adventitious tissues resulting from inflammation, were brought into such relations. I use this expression, "brought into such relations," designedly. For at my last lecture I argued, in accordance with the principles laid down in previous lectures, that there could be no spontaneous generation of blood and vessels in a mass of effused and organizing lymph; and that there could just as little be a voluntary pouching out of neighboring blood-vessels into such a mass. It would not be possible, I think, to demonstrate either occurrence; but nothing short of demonstra-

tion could establish the fact of a process so wonderful and improbable as either of these things would be.

But the fact remains, that we find in adhesions formed out of inflammatory lymph, capillary channels through which blood flowed during life. And these channels, and the blood they contain, must have been produced by outgrowth,—not, observe, by *spontaneous* outgrowth,—from the already existing vessels of the adjoining tissues.

The question then presents itself, how does this outgrowth take place? You will not be surprised, after the views already laid before you, if I deny that it is by virtue of any power except such as resides in the elements for whose benefit the outgrowth is to be effected. Here, indeed, it seems to me that we have the only clue to the correct explanation of the process.

The mass of new tissue-elements, then, which constitutes organizing lymph, and the mode of whose origin has been so lately the subject of our inquiry, needs nutritive material, in fulfilment of one of the essential conditions of the life-process. And if a sufficiency of nourishment can be obtained by imbibition, as by articular cartilage for example, there will be no development of new blood-vessels.

But if the demand is too great to be thus complied with, it must be felt more at certain portions of the extent of each vessel skirting the theatre of the new deposit than at others. And at every such point there will be of course a greater attractive force exerted upon the blood-current passing along the vessels than there will be elsewhere. But, as I have before urged, the capillaries are mere tubes,

yielding to pressure either from within or from without; and if, at every such point, the blood is attracted, there must be a tendency in the blood to obey the attraction, and to push before it the yielding membrane of the capillary wall. Hence we shall have, at every such point, a pouching outward of the vessel.

Perhaps it may not be too great a refinement to assume, that in being so pouched out the wall of the vessel loses in thickness; for according to this view it does not, at first at least, grow, but is stretched. And being thus thinned, the wall of the pouch becomes more ready to give than it was before, besides which its shape is such as to offer less resistance than when it was that of a simple tube. It only remains for two such pouches to yield towards one another, and to give way, to establish a vascular loop; and the whole of what seems to me to be the true theory of the vascularization of lymph is before you.

In the same way I would account for the development of lymphatic vessels in these new formations. The minute injections of Prof. Van der Kolk, which prove the existence of such vessels, have never, so far as I know, been suspected of inaccuracy. They deal only with adhesions between the costal and pulmonary pleuræ, when the lymphatic system is abundant and exceedingly active, and where, therefore, such a development would be more likely to take place than in most other parts of the economy.

Very little is known of the physiology of the lymphatics, in comparison with that of the other great systems; and hence we can only argue from analogy

in regard to the point now in question. Let me simply say that it would be entirely gratuitous to assume here a power of spontaneous outgrowth which is not held to exist in the blood-vessels; and that it would be still more unreasonable to suppose that newly organized lymph, if unable to generate its own vascular system, could originate what in the perfect economy seems to be a mere dependent or accessory to the former.

Again, the arguments against the idea of an independent formation of vessels and blood within effused and organizing lymph would obviously apply with even greater force against that of such a formation of nerve-fibres. Nor is there any reason whatever to suppose that neighboring nerves have of themselves any more power to send out processes into newly deposited lymph than into fully-formed articular cartilage. And as the instances observed by Virchow stand alone, among the countless cases in which no such nerve-formation has been discovered or suspected, it seems as if we might well content ourselves with accepting the fact as stated by him, and waiting for further opportunities of studying the phenomenon.

Lymph, then, is a substance separated from the blood of an inflamed part by the agency of the irritated tissues of that part, and is probably due to a proliferation or a division of the existing tissue-elements. It may assume the condition of ordinary connective or areolar tissue, and in the great majority of cases this is its ultimate state. Or it may be further developed into bone, epithelium, cartilage, or, possibly, even into nerve-fibres. Generally, how-

ever, the forms assumed are those of the merely mechanical structures; even when epithelium is formed, it is not fully endowed, for there is no evidence of its playing its usual part in secretion.

I would call your attention to the fact that in this statement, as in those which preceded it, there is neither expressed nor implied the idea that in the original constitution of inflammatory lymph there is any incapacity to undergo the highest degree of development. But the outside influences to which the adventitious substance is exposed are not such as to induce such a process—and hence, merely for want of favoring circumstances, the development undergone by lymph is never above a certain grade. My own belief is that in any mass of inflammatory lymph there is the same capacity for the formation of brain-tissue that there is in the cells to which the segmentation of the ovum gives rise; but in the one case the collateral conditions necessary are wanting, while in the other case they are present.

The position, then, of the lymph which results from inflammation, may be indicated in very few words. It becomes a living tissue, and may go on, under the influence of circumstances, to the assumption of further and perhaps higher characters. Should those circumstances be present, this development must occur in implicit obedience to them; if they are absent, it cannot occur by virtue of any inherent tendency in the effused substance.

I think we can now reason intelligently as to the office of lymph in the repair of injuries. Its presence in such cases is not due to a provision made with a view to the healing, but is simply a result of the in-

flammation which is excited in the neighboring textures. But being present, and becoming a living tissue, it undergoes development in relation with the injured parts, so as to constitute bone in cases of fracture, connective tissue, etc. in lesions of other structures. Prof. Virchow, in his "Handbuch der Specielle Pathologie und Therapie," says: "An ossification which appears very useful as a uniting callus between the two parts of a broken bone, may constitute an actual exostosis if it occurs in a stump after amputation." (Vol. i. p. 333.) Instances are, as is well known to most of you, constantly occurring in which outgrowths of bone result from inflammation. I have lately seen two very striking examples of the kind; in one the contact of a ball lodged close to the femur had given rise to a number of small knobby exostoses on that bone, while in the other an extensive necrosis of the femur after amputation caused inflammation of the entire stump, with conversion of a large mass of the effused lymph into osseous tissue. (Perhaps it should be stated that no microscopic examination of the structure was made, but the extreme hardness and the other gross characters presented by it could scarcely be mistaken.)

And in view of the fact that inflammation cannot but take place, and generally is plainly observable after fractures, it seems to me to be much more reasonable to ascribe the origin of the lymph which becomes the uniting medium to this, rather than to the influence of some obscure and newly developed sanative agency. Such a theory accords with what appears everywhere else in nature, — the accom-

plishment of various ends by the operation of simple laws.

Upon the principles now laid down, it will be easy to see that the tissues thus developed by the organization of inflammatory lymph must be amenable to all the laws, and affected by all the influences, to which the rest of the economy is subject. These tissues have a nutrition, which may be disturbed in different ways. It may undergo the same changes, by irritation, as any other portion of the economy—so that an adhesion itself due to inflammation, may in its turn become inflamed. It may be impaired, and atrophy result. Any defect in the nutrition of the entire system will be especially felt by it; and herein may be found the explanation of those cases in which the united ends of a broken bone are separated afresh, or old wounds reopened, in persons who become the subjects of syphilis or scurvy.

In such a case of atrophy, there may be not merely a loss of consistence, but an actual absorption and disappearance, of the material which was the bond of union. How can this be explained? Obviously it is a very different thing from that lessening of bulk which takes place in a part which has been the seat of lymphization, to use Prof. Gross's term, and which is probably due to the change of condition of the new elements, as they become condensed from juicy and succulent cells into regular fibrous or connective tissue.

One of two explanations must apply to this disappearance of the adventitious material. Either the elements composing it must be broken down struc-

turally and chemically, so as to become capable of solution or actually dissolved, in order to pass through the capillary walls into the blood-current, or they must be thrown off by ulceration; in the latter case a process of breaking down will also occur, probably identical or nearly so with that which takes place in the former. Neither of these modes of disappearance can be practically studied, but on general principles we may assume the statements just made to be correct.

Mr. Paget has given a brief but excellent exposition of this subject in the admirable Lectures which I have already quoted so often. Besides the mere wasting, probably by absorption, of the lymph formed in inflamed parts, he mentions calcareous and pigmentary degenerations as apt to be observed in it. The apparently bony deposits in the pleura or pericardium, before alluded to, may be adduced in illustration of the former; the latter is generally met with near places where pigment is normally deposited, as for instance in the pulmonary pleura in the neighborhood of the bronchial glands.

I think, gentlemen, that the views which have now been presented to you with reference to the origin and development of inflammatory lymph are altogether in accordance with those laid down in regard to the healthy process of nutrition. My endeavor has been to follow as closely as possible the natural course of the subject, so as to avoid side-issues, and to keep hold of the clue which, beginning in the normal, should guide us to the true conception of the relation between it and the abnormal.

It yet remains for us to study the other substance

which was mentioned as a product of inflammation, —pus. For, let me remind you, I took the ground that there were properly speaking but two such products, viz.: lymph and pus. And I remarked upon the fact that of all the phenomena which belong to this disease, no one alone except the presence of one or the other of these two substances constituted positive evidence of it. Perhaps this statement ought to be somewhat qualified, as regards lymph, which is I think occasionally met with where it can hardly be supposed that the parts could have been actually inflamed, without much more trouble in the economy than has been experienced. Thus about the base of the brain there are sometimes seen irregular masses deposited, presenting all the characters of lymph, although the clinical history of the case may not afford any evidence whatever of an inflammatory origin for them.

Still, as a general rule, where deposits of this kind are found, they may be regarded as results of inflammation; and such is invariably the case with pus. And without anticipating, it may be said here that while we have seen that the formation of lymph tends to the increase of solid constituents in the organism, we shall find on the contrary that the formation of pus is altogether degenerative. So far as inflammation is concerned, it is in either case an affair of interference with nutrition; in either case the normal process of nutrition is impaired. But the formation of lymph is manifestly nearer to the maintenance of life and structure, than that of pus.

The physical characters of ordinary pus are very familiar to you; its yellow color, its creamy con-

sistence, its greasy feel, its sweetish taste, as well as the peculiar odor which belongs to it when in quantity, and which it leaves on the hands of those who have much to do with surgical cases. Such are the qualities of what has received the name of *healthy* or *laudable* pus. Different specimens of it vary, however, in several of these points—in some cases it is much more fluid than in others, while its yellow color may present a more or a less decided greenish tinge.

Now on the ground taken in my first lecture, that inflammation was always, wherever met with, a disease, you will perceive that it cannot be regarded as strictly correct to speak of healthy pus. And yet, adopting as a standard that form of this product which is observed to occur in healing wounds or in simple abscesses, and which corresponds with the description before given, it is evident that there is a certain propriety in calling that which comes up to this standard normal. Such pus is innocuous; and therefore differs from the contagion-bearing pus of gonorrhœa, or from the pus of an ulcerated cancer. Compared with such products, what is called healthy or laudable pus seems fully to merit such epithets. Let it be understood, however, that this mode of expression is not strictly, but only relatively correct; that the presence of pus is infallible evidence of a departure from absolute health in the organ or tissue from which it is derived. Outside entirely of the programme of healthy life, lymph and pus have for themselves a natural history, which may be in various degrees adhered to or departed from.

In some cases, especially in what are called chronic or cold abscesses, the pus differs very widely from the description just given—being mainly composed of a thin watery or serous liquid, with curdy flakes floating in it.

Very often pus is streaked with blood, and sometimes it is intimately mixed up with it, as in the rusty sputa of pneumonia. And in cases of ill-conditioned sores, the local formation of pus being deficient, and the blood-mass at large being impoverished, we find the discharge to consist of a thin, reddish, irritating liquid, which has received the name of sanies. Whenever the unctuous feel and thick consistence of pus are diminished, it loses also its bland character, and becomes acrid, so as sometimes to scald and excoriate the skin or mucous membrane over which it chances to flow. Probably in such cases the liquid exchanges its usual chemical reaction, which is nearly neutral, for an acid one.

According to Simon, the specific gravity of pus taken from the human subject varies from 1027 to 1040. He quotes from Göbel the analysis of pus from the uterus of a mare, the specific gravity of which was 1079.

As to the chemical composition of pus, the results obtained by different observers are, as might be expected, somewhat at variance. Water, fatty matters and cholesterine, albumen, salts of lime, soda and iron with carbonic, sulphuric and phosphoric acids, chlorides of sodium and potassium, are the chief ingredients detected. Some of these are present only in very small amount. The main inference to be drawn from the results of these analyses is that

pus is the product of the breaking down of the structures normally composing the economy.

When pus taken from a simple abscess, or from a healing ulcer, is put under the microscope, it is at once seen to consist of certain solid constituents, floating in a liquid menstruum; and thus to resemble the blood. Some of the early observers, indeed, thought that it was nothing more or less than altered blood; but this idea has long since been abandoned.

Mingled with the elements strictly belonging to pus, are often found fragments of the degenerated or broken-down tissues; epithelial cells, shreds of connective tissue, and oil-drops, are the most familiar of these forms. Often, especially when the pus has been retained for a length of time in the cavity of an abscess, its own solid constituents are in process of breaking up, and exist only as crumbled fragments.

The pus-cell, however, when perfect, is a spherical nucleated cell, bearing a good deal of resemblance to the colorless corpuscle of the blood. According to Wedl, there are marked variations in size in the pus-cell. "It is as yet undetermined," says he, "whether these diversities of size are connected with the individual by whom the pus is afforded, or with the nature of the disease, as J. Vogel supposes, who has remarked that the size of the pus-corpuscles of an abscess and of a wound is tolerably constant—in the one case they are all small, and in the other all large."*

The number of nuclei contained in these elements

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* Pathological Histology, p. 295. (Syd. Soc.'s Translation.)

varies from one to five—the number most generally seen, however, is three. These nuclei are strongly brought out, as in other cells, by the application of acetic acid; each one contains a bright nucleolus.

Very commonly, perhaps almost always, pus-cells contain a greater or less quantity of minute oil-drops; a fact which may be looked upon as connected with the degenerative character of the product.

In the Brit. and For. Med.-Chir. Review for Oct. 1864, I find a quotation of some singular observations reported by Dr. Von Recklinghausen in regard to certain changes of form in the pus-corpuscle. This writer claims to have seen in the cornea of the frog, infiltrated with pus, and in the aqueous humor, a shooting out of processes from the side of the pus-corpuscle; and by the movement of the mass of the original corpuscle towards the end of one of these processes, the corpuscle itself seemed to change its place. He says that "in the fresh condition of the human pus-corpuscle there is, besides the change of form, also a very lively molecular movement in the interior of the cells distinguishable, which movement becomes more active at those points where the processes protrude from the cell." Active changes of form were seen by him also, it is said, in the pus-corpuscles of a dog and of a rabbit; and he thinks that "the pus and mucus-corpuscles of vertebrata, at least during a certain period of their lives, possess contractile qualities, which are attested by the change of form and the so-called molecular movement."

In the *Arch. Gén. de Méd.* for Nov. 1864, I find also the following statements:

"A medical student recently presented himself to M. Szabadfoldy, having upon the glans penis two small pustules, which had existed only a few hours, and which there was strong reason to believe were syphilitic. The pustules were surrounded by an areola of vivid injection; their contents seemed transparent, and they itched violently. The author evacuated one of them by puncturing it with a fine-pointed needle, and placed the fluid which escaped under a magnifying power of 300–350 diameters. He found it composed, in about one-third of its contents, of cells, some rounded, some furnished with prolongations. These latter changed their form under the eye of the observer; from being rounded they became ovoid, and their appendages appeared and disappeared by turns. In some they were so numerous as to give the cell the appearance of being ciliated, as for instance when five or even eight prolongations existed on one face of a cell. Some of the cells were elongated, and are compared by the author to fusiform cancer elements. Beside these were others which recalled completely the large cells with numerous appendices met with in some cancerous tumors. It was in these cells that the most remarkable changes of form were observed; besides, the contents of many of the cells presented a very elegant molecular movement.

"The movements observed in these various elements became slower at the end of 3 or 4 minutes. The addition of a drop of acetic acid caused them to cease altogether, while all the prolongations vanished. The author subsequently examined the drop of liquid which remained in the pustule, but found only pus globules in it. The liquid taken from the other pustule showed contents analogous to those of that obtained from the first, but the characters were less marked.

"No treatment was instituted, and a clearly chancrous sore succeeded to the pustules. The liquid from it showed no unusual characters.

"The author has had but one opportunity of making an observation of this kind, on the pus from a chancre seated in the urethra. (*Archiv für Pathol. Anat.*, t. xxix., liv. 3 and 4, 1864.)"

I can only mention these statements to you, without expressing any opinion as to their reliability, or their value in pathology. So far as my knowledge

goes, they stand alone; and no opportunity has occurred to me of testing their accuracy by repeating the observations upon which they assume to be founded. It would seem somewhat strange, however, if such changes of form, and such movements, were now for the first time noticed, notwithstanding the great attention that has been paid to the study of pus-cells by so many intelligent and laborious pathologists. And perhaps, even if it were placed beyond a doubt that such changes did take place, they would prove to be simply the accidental effect of endosmotic currents through the cell-wall.

Another solid element sometimes observed in pus, and described by most authors as particularly constant in pneumonia, is what was at one time known as the exudation-corpuscle. It is a spherical body, consisting apparently of a mere aggregation of granules; in size it exceeds the pus-corpuscle, but it is much less abundant. No satisfactory theory has been offered as to its origin or nature. I have seen this element in pus from the horse.

Wedl says that while some pus-corpuscles, and particularly the larger forms, exhibit a cell-membrane, they seem in most cases to be bounded simply by a delicate granular material. Upon what grounds this statement is based, does not appear from his description. Vogel also speaks of a nucleus surrounded by an indefinite, granular, amorphous precipitate, without a clear outer circumference, and as its behavior in relation to endosmosis shows, without a cell-wall. His statement is much less general than that of Wedl. It certainly would be, however, a strange thing if without any differ-

ence in origin or purpose, and without any other structural variation, so striking a difference should exist between two sets of cells. It seems to me more correct to say merely that the cell-wall is more plainly developed the larger the corpuscle itself is.

Now according to all the analogies afforded by histology, whether physiological or pathological, the multiplicity of the nuclei of pus-cells is simply an index of the process of division which those cells are undergoing. This division would seem to be the mode of multiplication of the cells, and its almost constant occurrence agrees well with the extreme rapidity of formation of pus so often observed.

We find, then, as one of the products of inflammation, a liquid containing in it certain cells, and these cells exhibiting evidences of rapid multiplication in the breaking up of their nuclei. We have ample negative evidence that these cells are incapable of further development, but that they are either wholly discharged from the economy, dried up into inert masses, or disintegrated and reabsorbed.

Two main questions arise in regard to these cells. The first is, how are they formed? The second, what is their relation to the normal elements of the organism? As will be seen, these questions are not wholly distinct one from the other.

Precisely as in the case of lymph, the origin of pus-cells may be explained in either of two ways. They may arise out of a homogeneous liquid exuded from the vessels, by a process somewhat similar to that of precipitation or crystallization, or they may be legitimately descended from elements already existing. There have indeed been authors who en-

tertained the idea that the pus-corpuscle was merely a blood-corpuscle which had undergone change. Gendrin even went so far as to describe with apparent accuracy the nature of the progressive changes between the two forms. But this idea, although I believe it had at one time the support of Donné's authority also, has now been long since abandoned. The only wonder is that it should ever have been endorsed by men of so high reputation as observers.

One author, Mandl, actually applies the term precipitation to the process; his description of it does not differ from that of Vogel, which is as follows:

"The process of the formation of pus from a fluid cytoblastema can be best observed in fresh wounds cleansed from blood. In examining the fluid secretion from a wound, we first observe minute granules, less than the 1000th of a line in diameter, which are chemically identical with the molecules insoluble in the alkalies and in solutions of borax. There then appear, partly around these molecules and partly independent of them, somewhat larger corpuscles, soluble in the alkalies, but not in acetic acid, identical with the nuclei of the pus-corpuscles. These nuclei appear sometimes isolated, sometimes in groups of twos or threes, thus forming composite nuclei; around these the cell-wall is subsequently developed, first appearing as a pale transparent membrane, and subsequently becoming thickened and granular; and thus the pus-corpuscle is formed."

The entire analogy which obtains between this description and that before quoted from Schwann in reference to cell-formations in general is at once evident. It corresponds also with the views held by most other writers on the subject. For instance Hassall, in his elaborate work on the Microscopic Anatomy of the Human Body, maintains that the

pus-corpuscle is an undeveloped epithelial cell; and in describing the mode of formation of epithelium, he gives a rationale identical with that just quoted from Vogel. Hassall, however, differs from all other authors with whom I am acquainted, in that he thinks that the pus-corpuscles may be developed into a protecting epithelium; an opinion which does not seem to rest on any adequate foundation.

Donné, in his elaborate work on Microscopy,* takes the ground that the formation of pus is a true secretion. He says:

"Thus I do not admit that the globules of pus are formed at the expense of the fibrin of the blood—that they can be considered as a sort of precipitate of the fibrinous part of the liquid blood; and notwithstanding their analogy in structure and composition with the colorless blood-corpuscles, I do not admit that they have anything in common in their origin or intimate nature with these latter. I regard the pus-globules as a product of special and direct secretion of the suppurating part, of the pyogenic membrane."

In further support of this view, he quotes the authority of Bérard, one of the contributors to the Dictionnaire de Médecine. After all, however, it does not seem to me that this does anything toward the clearing up of the question. It makes very little difference whether we call the process of formation of the pus-corpuscle a secretion, a precipitation, or by any other one word, so long as we do not describe it with accuracy. The first thing to be done is to ascertain how the forms met with are produced, and then the term to be applied to their mode of origin may be arrived at without much difficulty.

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* Cours de Microscopie, p. 191. (Paris, 1844.)

Nor does it throw much light upon the process of suppuration to say, with Hassall, that the pus-corpuscles are simply young or undeveloped epithelial-cells, unless we are prepared to show how the latter acquire their organization.

A much more rational view, because one which goes deeper into the philosophy of the matter, is that taken by Paget. This is that pus is the result almost always of the degeneration of lymph; the exceptions being those surface-suppurations noticed in the conjunctiva and urethra, when there seems to be exuded upon an unbroken surface a liquid, which is first recognizable in the character of pus. Of the former occurrence there are instances continually presenting themselves, as in almost every abscess. Paget's description of it is so excellent, that I cannot forbear quoting it.

"The change," says he, "almost always begins at or near the centre of the lymph, where, we may believe, the conditions of nutrition are most impaired. It may extend from a single point, or from many which subsequently coalesce. In either case, the central collection of matter remains surrounded by a border or wall of indurated tissue, in which the infiltrated lymph is not transformed into pus, but rather tends to be more highly organized. This border or peripheral layer of lymph now forms the wall, as it is called, of the abscess, and the finger may detect, as the best sign of abscess, a soft or fluctuating swelling with a firm or hard border. The expressions commonly used are, that the suppurative inflammation has taken place in the centre of the swelling, and that its effects are bounded by the adhesive inflammation; it might be said with the same meaning, but perhaps more clearly, that of a certain quantity of lymph deposited in the original area of the inflammation, the central portions have degenerated into pus, and the peripheral have been maintained or more highly developed; and probably we may add in explanation, the difference has depended

on the degrees in which the conditions of nutrition have been interfered with in the places in which the two portions have been seated. In the central parts of an inflammatory swelling, the circulation, if not wholly arrested, must be less free than in the peripheral; the blood, moving very slowly, or stagnant, must lose more of its fitness for nutrition; the tissues themselves are more remote from the means of maintenance by imbibition; in these parts, therefore, degeneration, if not death, ensues, while in the peripheral parts maintenance, or even development, is in progress."*

I think it must be evident from the recounting of these various theories, that there has been a constant progress towards a satisfactory theory of the formation of pus. First there was the one, which would naturally suggest itself when the pus-corpuscle was discovered, bearing a relation to the liquor puris analogous to that borne by the colorless blood-corpuscle to the liquor sanguinis, that the whole substance was simply altered blood.

This being shown to be untenable, the idea occurred that a homogeneous liquid was separated from the blood, in which the pus-corpuscles were developed by chemical precipitation or by a process of spontaneous generation.

Next would come Donné's view, that this process, for it must have been in no essential point different from that just mentioned, belonged among the secretions, being analogous to the formation of bile, saliva, or urine.

And as the rationale of secretion, and the physiology of the mucous membranes, became more fully understood, Hassall's theory that the pus-corpuscle

* Op. cit., p. 250.

should be regarded as an undeveloped epithelial cell presented itself with much force. This idea evidently belongs to the modern school of pathology, based on physiological anatomy.

The next step is the view so well set forth by Paget, in regard to the mutual relation existing between pus and lymph. But, as was before remarked, there are exceptions to which this theory will not apply. These however would seem to be covered by that of Hassall.

If now we can reconcile these two, and show that, while one applies to one set of cases, the other answers for the rest, and if we can so generalize the idea as to bring it into the shape of a law which shall cover the whole ground, it is obvious that we shall have done as much as could be looked for in the existing state of things. Possibly the further progress of investigation may overset all the theories of the present day, as has so often happened to theories which doubtless seemed to their supporters to be firmly established; but for this we need not look. All that can be done in any science is to reason upon the facts so far as they are known; all that can be learnt from the failure of former systems of philosophy, or from the demolition of former theories, is that those who would propose new ones should do so with modesty.

In regard to the matter now in hand, it seems as if the modern German school had made a great advance in establishing the theory of the legitimate descent of every cell from a pre-existing one. This theory has been already dwelt upon in connection with the development of lymph; and if it is of equal

force with reference to the formation of pus, so that the two products can be shown to acknowledge a common or a like origin, the value of the step gained need hardly be pointed out.

Pus, as is manifest, can be produced either upon a surface or within the substance of the tissues. It may be formed on the outside of the body, as in an ulcer, or in the substance of a tissue, as in the interstices between two muscles; on the bronchial mucous membrane, or in the substance of the liver. But whatever its situation, it is to be regarded, according to the doctrines of the modern school, as the result of the proliferation, by division, of the cells either of connective tissue or of epithelium. In the words of Virchow:

"Pus is in our opinion a young tissue, in which, amidst the rapid development of cells, all solid intercellular substance is gradually dissolved. A single connective-tissue cell may in a very short space of time produce several dozens of pus-cells, for the development of pus follows an extremely rapid course. But the result is of no service to the body; *proliferation becomes luxuriation.* Suppuration is a mere process of luxuriation, by means of which superfluous elements are produced, which do not acquire that degree of consolidation, or permanent connection with one another and with the neighboring parts, which is necessary for the existence of the body."*

In order to complete the theory, let us look at the application of this same idea to the formation of pus upon surfaces, or from epithelium. This is even more easily conceived of. Take for example the lining membrane of the urethra. Here there are

* Cellular Pathology, p. 445. (Chance's Translation.)

several strata of epithelium, and if inflammation occurs, there is a very rapid throwing off of pus, without in the vast majority of cases anything like ulceration. It is much more reasonable to suppose a quickened formation of these epithelial cells, with at the same time a disposition to divide up into new cells, and an inability to acquire full development, than to imagine a homogeneous liquid poured out, certain atoms of which, by common consent, and by a spontaneous impulse, aggregate themselves together into organized forms.

LECTURE VIII.

THE STUDY OF PUS CONTINUED—ITS RELATIONS WITH LYMPH—WITH CONNECTIVE TISSUE—WITH EPITHELIUM—HISTOLOGICAL SUBSTITUTION—RELATIONS OF PUS WITH OTHER TISSUES—PUS HAS NO SOLVENT POWER—RELATIONS OF PUS AND MUCUS—FINAL DESTINY OF PUS — ITS OBJECT NOT PROTECTIVE — PYOGENIC MEMBRANES, SO CALLED—ULCERATION—ITS RATIONALE—TYPICAL CASES—THE PROCESS A NEGATIVE ONE.

We have this evening, gentlemen, to continue the study of the subject of pus. You will recollect that at my last lecture, after speaking of the physical characters of this substance, I mentioned the various theories which have from time to time been proposed as to its mode of origin. I endeavored to show that none of those based upon the idea of chemical precipitation, of spontaneous genesis, or of the merely transitional character of the pus-cell, were satisfactory. Here, as in the case of lymph, the views of the modern German school, as set forth chiefly by Virchow, seem to me to accord best with the known facts.

I took the ground, therefore, that pus was a product of the proliferation of cells previously existing. In this origin it is analogous to lymph; but while the latter may, and generally does, go on to a further development into more or less permanent forms, pus has as such reached its highest state. The lymph-cells may assume the character of fibrous tis-

sue, of epithelium, possibly even of nerves, although this latter idea rests upon an excessively slight basis even for so guarded a statement. Pus-cells, on the contrary, can undergo no change except in the way of degeneration and decay.

The lymph-cell may be, owing to circumstances, a mere transition-form between connective tissue or epithelium and pus; the converse can never be the case.

Hence we have at one end of the scale the normal structures, connective tissue and epithelium; at the other, pus; and between these, lymph. Inflammation taking place, either lymph or pus may be developed from epithelial or connective-tissue-elements; if lymph, it may either assume the character of the progenitive structure, or degenerate into the effete condition of pus, whose only feature in common with living organisms is its cellular form.

Such a theory covers alike cases in which, as in purulent conjunctivitis, we cannot admit the idea of a previous development of inflammatory lymph, and those in which, as in many abscesses, such a development manifestly precedes that of pus. Moreover, it does away with the necessity of a purely gratuitous assumption of the power of spontaneous generation of cell-forms in a homogeneous liquid.

Wherever, then, we have connective tissue, or epithelium, in sufficient quantity, we may have pus as a result of inflammation. Should, as is often the case, perhaps it may be said always in interstitial inflammations, a deposition of lymph first occur, then the pus will be in part derived from the conversion of this lymph, and in part from that of the tissues.

Now in the pus derived from a mucous surface, one is very apt to find upon careful examination that there are here and there mingled with the pus-cells the elements of epithelium, either normal, or in various stages of disintegration. And so also in the pus from an abscess, we often are able to detect shreds of broken-down connective tissue, which has simply become effete instead of going through the degenerative conversion into pus. Hence all the epithelium, or all the fibrous tissue, does not become involved in this process of pyogenesis. I think it may be said that it is only the young or newly-developed elements which are thus dwarfed as it were, and perverted; the fully-formed ones dying, indeed, from interference with their nutrition, but not going back first into their succulent and undecided form, to take a fresh start in a direction which should lead them at length to the state of pus.

An idea which will very probably have occurred to some of you in the course of this discussion, is that in one of the cases of suppuration now supposed, epithelium alone is present to be so changed, while in the other there is nothing but connective tissue available as a source of the pus. In the earlier days of physiology, this fact would very probably have been held as affording a conclusive argument against the theory that one and the same substance,—pus,—could be derived from the degenerative metamorphosis of either of two tissues so different, in the eye of a superficial observer, as connective tissue and epithelium. But I think it may be stated as a view sanctioned by all that is known at present of

the origin and development of the tissues, that, coming from a common stock of germs, the various elements assume their distinctive characters quite accidentally; according of course to a certain preconceived model, and not to any whim or caprice. Those germs, however, which become elaborated into the substance of the spinal cord, might just as well have been developed into epidermis or muscle, had their place been different. It is true that in the two instances just mentioned, of the nerve-tissue and muscle-elements, we have organisms which have received properties which set them entirely apart from such, for instance, as bone, connective tissue, or epithelium. And of these three, the earthy deposit which has taken place in bone has given it a strongly distinctive character, wholly independent of the analogies which may be deduced from its form and the nature of its function.

I have several times had occasion to allude to the relation between connective tissue and epithelium, but have not yet spoken definitely of it. Perhaps you will excuse my placing before you another quotation or two from Virchow's "Cellular-Pathologie," which will illustrate the point better than any words of my own could.

In speaking of the so-called "law of continuity," proposed by Reichert, he says that—

"It soon sustained the heaviest shocks, and of late has been so battered to pieces, that it is no longer possible to deduce from continuity any general criterion for deciding upon the character of a tissue. On the one hand, new facts have been continually presenting themselves in proof of the continuity of such tissue-elements, as according to Reichert should be separated *toto cœlo*, for example, of epithelial and

connective tissues; instances have accumulated of cylindrical epithelium cells, prolonging themselves into fibres, which as such become attached to connective-tissue corpuscles. Indeed, there have quite lately been adduced numerous proofs that such cells may extend from the surface inwards to enter into immediate relation with nerve-fibres. Of this latter statement I must say that its correctness has not yet been proved to my satisfaction; but as to the former, that is a matter which seems likely to end in the establishment of a relation of continuity between the elements named. It would therefore appear that it is no longer possible to draw the line exactly between every kind of epithelium and every kind of connective tissue, except in the case of the former being tessellated; when it is cylindrical, the boundary cannot but be very doubtful."

After making similar statements in regard to the continuity of muscular and connective tissues, the author goes on to say:

"Something else must therefore be substituted for the law of continuity. Here, I believe, is the essentially proper place of the doctrine of *histological substitution*. In regard to all tissues which are similar in their character there is a possibility, as occurs physiologically in various classes of animals, of the substitution of one by another of the same group in any given portion of the body; in other words, by a *histological equivalent*."*

In support of this view, Prof. Virchow adduces various examples of the substitution of one form of epithelium for another—that of the cartilaginous structure of the sclerotic coat of the eye in certain fishes, while in man that tunic is composed of dense fibrous tissue—that of bone where cartilage previously existed—and finally that of striated muscle in some animals in parts which in others are made up of the non-striated kind.

* Op. cit., Lecture III.

Let me recall to your minds an instance of this histological substitution which I mentioned to you when speaking of the development of lymph in inflammatory adhesions; where, of a mass of adventitious cells, while the interior ones assumed permanently the form of connective-tissue-elements, those on the surface acquired the character of more or less perfectly constituted epithelium.

In applying this idea to the case of pus, it is only necessary, instead of supposing one starting-point from which a number of different forms are developed, to reverse the plan, and imagine a deterioration of several varieties of tissue-elements into one common effete condition.

And here the question may be most pertinently asked, what are those varieties which so deteriorate? Besides connective tissue and epithelium, there are often other structures, muscular, nervous, glandular, present in parts which are the seats of suppuration; do they furnish pus-cells, or are they, as was stated in regard to fully developed fibrous elements, apt to be merely necrosed and thrown off in the state of debris?

To give a direct answer to these questions is not easy. A muscle may be inflamed, and pus may be developed in its substance—but whether the pus-corpuscles owe their origin exclusively to the degeneration of lymph, and of the connective tissue which always enters into the composition of a muscle as such, or in part also to the proliferation of the special elements of the muscle, has not yet, so far as I know, been decided by actual observation.

As to gland-tissue, it is certain that in many cases, as for instance in the abscesses in the parotid region

which sometimes follow typhoid fever, the connective tissue in the neighborhood of the gland, and not the gland itself, forms the seat of the inflammation. And when, as in the lymphatic glands, these organs are themselves manifestly affected, there is scarcely anything present but connective tissue and epithelium; so that here there is no difficulty in assigning the source of the pus.

As regards the share taken by nerve-structures in this process, it seems to me probable that the finer nerve-filaments which enter into the formation of the skin, for example, are broken down and destroyed much in the same way as the fully-formed connective tissue to which allusion was before made. It may be that some of the oil-drops and phosphatic salts which exist in pus are simply the debris of nerve-filaments. Nerve-trunks, when they run across the area of a suppuration, seem to maintain their integrity. I have seen the ulnar nerve stretching across the cavity of an abscess at the elbow; it was indeed in a state of incipient fatty degeneration, but its fibrous envelope was still perfect.

I think it important in this connection to state formally that there is no ground whatever for the opinion which had at one time, and perhaps still has, a place in the creed of many pathologists, that pus might act as a solvent of sound tissues bathed in it. This idea was probably derived from the appearance often presented by bone which has been exposed by the loss of its periosteum, and in contact with a purulent deposit; such a portion of bone is apt to be brittle, roughened, and its surface irregularly worn away, as if worm-eaten. Actual experi-

ment, however, has shown that the solvent power of pus is only imaginary; the appearances just mentioned being produced simply by the failure of nutrition in the tissue, causing it to waste and decay. Bone that is killed may indeed crumble away, and be discharged either as a gritty debris or in actual solution, along with the pus of the abscess which existed around or alongside of it.

Of this I have seen a striking instance in a soldier who was wounded by a small-sized conical bullet, which passed directly through the wrist from one side to the other. When he came under my care, some months after the receipt of the injury, a probe passed along the track of the ball came in contact with carious bone. Gradually, however, the discharge of matter became less and less, the openings closed up, and with the exception of deformity and loss of power, the member became perfectly sound. Here it is absolutely certain that the dead bone was brought into a state of very minute division, if not of entire solution; not because of any solvent power in the pus as such, but simply because the spongy character of the bone itself favored its disintegration.

The idea, then, which I would substitute for this one of the solvent power of pus over tissues bathed in it, is simply that, the nutrition of such tissues being impaired, they become atrophied and disintegrated, and at length disappear. Undoubtedly, when pus is acid, and it is kept in contact with a portion of bone, it will like any other acid liquid decompose the earthy salts of the bone, and thus favor its atrophy and breaking down or absorption.

But this is very different from the idea that pus, as such, possesses a solvent power.

The relation between pus and mucus has been, since the earliest days of microscopy, a subject of doubt. Perhaps, indeed, the study of the forms belonging to those substances respectively only added to the confusion, since there was but a new element introduced into the question, without any direct increase of light on the main point. We must go back of these structures, and look at the entire group which they form with epithelial cells, in order to arrive at anything like a satisfactory idea of their relation.

We have sometimes, when a mucous membrane is not very severely irritated, or in the earliest stages of its inflammation, a flow of mucus, a glairy and more or less viscid liquid, from its surface. Placed under the microscope, this liquid is seen to be almost homogeneous, but containing some rounded corpuscles, sometimes with more or less fully-formed nuclei, sometimes without. Acetic acid often brings out nuclei in these bodies, which had not previously been visible. Mingled with elements of this kind are apt to be epithelial cells, which very generally are effete and breaking up. Such appearances may be found in almost any specimen of mucus from the nose or bronchial tubes in cases of catarrh—and nothing is added to them unless the inflammation becomes very greatly aggravated.

Here then we have an increased development of epithelial forms, but in a very crude and immature state; and this it seems to me is the explanation of mucus and its origin.

If the parts become more and more inflamed, we have more and more the characters of true pus in the discharge. There is a wider deviation from the ordinary normal type of the elements developed on the surface, and those which arise are no longer merely crude, but they are derived from a rapid proliferation of the existing cells, under the influence of a powerful stimulus. And the mucous discharge will acquire the gross appearances of pus long before the microscope will reveal a change in the character of the contained elements. Hence there is a gradual shading off from the normal homogeneous secretion of a surface so irritated to the fully-formed purulent discharge. At the very first, perhaps, there is simply an increase of the thin liquid, for instance, which comes from the Schneiderian membrane, and which passes off by mere evaporation. The quantity of it is so much larger than normal, that it flows away. Then there comes a period when the epithelial cells, in their fully-formed state, are rapidly shed—and now new cells are also imperfectly formed, not distinctly nucleated —mere abortions, if we may so speak, of what should have been epithelial cells. Still later, there may be an actual formation of pus—the cells of the lower layers of epithelium undergoing a process of division or proliferation into what we now know as the pus-corpuscle, a product of such degenerative proliferation either in epithelial cells or in those of inflammatory lymph.

Now the question may be asked, does this division of the nucleus of the pus-cell ever go on to completion, and finish by inducing a like division in the

cell itself, so that in place for instance of one pus-cell with three nuclei, there exist three with one nucleus each, or one with one nucleus and another with two? It is difficult to give a positive answer to this question, since we can only take the pus-cell as we find it, and we do not know of any one specimen of it whether the effort at division of the nucleus has not exhausted its energies in the way of proliferation. For it must be remembered that the pus-cell is the exponent, if we may so speak, of an irritative degeneration—of a state of things in which while the part is stimulated, it is less able to respond fully and in the way of actual growth to the stimulus; and hence, owing to its parentage it has form—owing to the excitement which gave rise to its development it is impressed with a tendency toward multiplication—but at the same time, owing to the marked degree in which the normal conditions of nutrition were set aside, it has a less endowment of vital power than the regular offspring of the structures concerned.

Hence, no matter how effective the proliferation of any one pus-corpuscle might be, it would only augment the number of like elements; and there is no ground for assuming that this proliferation can go beyond the first generation. That is, assuming that from one connective-tissue cell, as Virchow says in the passage already quoted to you, several dozens of pus-cells are produced in a short time; not one of these has any tendency to assume any higher type of development; they may possibly every one of them tend to divide into several new forms, and thus to augment the quantity of pus

present; so that, had we examined the part a little later, there would have been more pus developed in it. But this power of proliferation goes no further; it cannot be substituted by a tendency in the pus-corpuscle to form a fibre, or to take on the character of an epithelial cell. And it would need more positive proof than now seems likely to be attainable, to show that the several cells, so generated by division, possessed any tendency themselves to undergo a like fissuration.

Whether this interpretation of the multinuclear character of the pus-corpuscle be correct or not, it is still probable that at the time when that organism comes under the eye of the microscopist, the power of proliferation is not possessed by it—so that, for example, such a cell containing three nuclei might be watched for hours, and it would not undergo separation into three new cells. For, according to the views which have been presented in the course of these lectures, it cannot be said that the agglomeration of atoms which form a pus-cell has received a power of independent life, so that they go on by virtue of their own force to divide into a progeny, somewhat as the womb of a parturient woman may empty itself after her death. Nor can it be said that at the time of the first formation of pus-cells there is such an impetus given in the direction of life as can only be exhausted after several generations. The fact is, that the first production of these cells, and every succeeding one, simply depends upon favoring external conditions. No tissue, organ, or congeries of cells has the power of setting itself to work to form pus. Should its nutrition be

disturbed in a certain way, an indirect result is that instead of the formation of new healthy or normal tissue-elements, there is a substitution for these of pus-cells,—a suppuration.

As to the final destiny of pus, it is decided altogether by circumstances. Sometimes, as when an ulcer is properly cared for, or when an abscess is opened, it simply is removed from the economy, and shares the fate of other refuse animal matters. Sometimes it dries up in the atmosphere, and by an admixture of dust and other floating particles acquires the firm consistence of what we know as a scab.

This drying up of pus sometimes seems to be accomplished upon a certain definite plan, as for example in the case of the smallpox pustule. Here the cuticle is puffed up by the presence beneath it of a deposit of purulent liquid. After a time the central portion of the raised cuticle becomes depressed or drawn in, and the contents of the pustule acquire a thicker and thicker consistence, until at length they dry up altogether. Whether the watery part of the pus is absorbed, or evaporates through the scab, I do not know; but I am inclined to think that the former is the case. Certainly the latter part of the history of a smallpox pustule differs materially from that of acne, impetigo, or any other sore of like kind, in which the discharge of the matter is followed by the filling up and healing of the breach.

Occasionally something similar seems to take place in abscesses, which dry up and diminish in size, and are said to have been absorbed. This is

most apt to occur in suppurations of lymphatic glands, and where the inflammation preceding the development of the pus has not been either very acute or very severe. But in fact the pus as such is not absorbed; it is only the liquid portions of it which are removed in this way, while there is left a cheesy, inspissated mass, which may ultimately be chemically broken up, and itself disappear.

Pus, then, never assumes a permanent relation to the economy as lymph so often does. It is either discharged altogether and at once, or remains on sufferance, as it were, until a slower process of removal can be effected. I shall have occasion presently to discuss the possibility of its entering the circulation and giving rise to further trouble, as many pathologists have supposed that it did in the cases of so-called purulent absorption.

An idea has been very prevalent, and perhaps still obtains general acceptation, that pus is a bland secretion, which is intended to protect the parts beneath it, as in the case of an ulcer. No doubt its presence is advantageous in this way, but I do not think this warrants us in speaking of it as a "natural dressing." For, as was remarked in the case of lymph, there are so many instances in which the formation of pus gives rise to extreme inconvenience, that we might just as well take the view that this latter was the object for which it was intended. The evil, like the good, is incidental. As in the case of every other natural phenomenon it is according to circumstances whether the comfort of living beings shall be promoted or interfered with. I would therefore regard the law under which pus

is formed as one of that system of laws which govern life. When the processes of life, as manifested in any mass of cells, are deranged in the way which we call inflammation,—when the nutrition of that mass of cells is, according to the views already set forth, at the same time stimulated and weakened,—there is a more rapid proliferation, a quicker but a less purposive formation of new cells.

Moreover, a close scrutiny of the conditions under which an inflamed part is placed, and by which it is compelled to give rise to certain new products,—lymph or pus,—will show that there is never either a capricious tendency one way or the other, or a prudent choice as to which will best serve the comfort or welfare of the part or of the animal. As I have several times before urged, the material elements blindly obey the immediate forces brought to bear upon them. Given the circumstances under which, according to the law impressed by the Creator upon all living tissues, pus is formed,—pus will be formed, be it on a surface where it acts as a bland protective layer, or under a tough fibrous membrane where it gives rise to the severest agony. As well might an unsupported stone refuse to obey the law of gravitation because a man stood directly under it, as the tissues pour out pus for their own dressing.

Before leaving this special topic of the natural history of pus, I must say a few words as to the very commonly received idea that a sort of special organ is formed in some cases, whose function is to secrete or give rise to pus, and which is called the pyogenic or pus-forming membrane. It is evident at once that such an idea is inconsistent with those

which I have set forth in regard to the mode of origin and histological position of pus. Those instances which seem to support it most strongly are cases of lumbar abscess. Preparations have been made, and are represented in many works on surgery, showing a sac, shaped according to the pressure of surrounding parts, and extending from the lumbar region even far down along the thigh; this sac having invested the purulent collection during life.

If, however, we examine any case in which a sinus or fistula has existed for a length of time, we find an entirely analogous membrane; and in very many old ulcers the same is true.

The fact is, the idea of this membrane is closely allied to that of pus being a secretion; and when we give up this latter, assigning to the pus-corpuscles the place merely of an organic individual which so far as its relation to the living economy is concerned is an abortion, we must abandon also the notion of a specially constituted membrane for its development. But it is readily seen that the presence of a mass of pus, insinuated as it were among the tissues and therefore tolerated by them, will keep up only a slight degree of irritation,—just enough and no more perhaps to induce the continual formation of a layer of new lymph to supply the place of that which, as the disease advances in extent, breaks down into pus. Just in the same way the continual flow of pus and other matters along a sinus or fistula will not only it keep open, but the tissues bounding it will be constantly stimulated to just such a degree that new lymph will supply the place

of that which proliferates into pus. In either case the process is altogether analogous to that of the breaking down of the central portions of a mass of lymph in the formation of an abscess, as described by Paget in the passage which I quoted to you in my last lecture. The only difference is that there is in the ordinary acute abscess a very thick layer of lymph about the central mass, while in the chronic abscess or in the sinus there is generally a very thin one, and it is often sharply defined. Sometimes, as in the case of a fistula in ano, there remains around the channel quite a quantity of solidified lymph, which even forms a marked swelling about the outer orifice—but this is usually in acute cases; in such as have existed for a length of time the encasing and less sharply defined portions of the adventitious substance are absorbed, and the morbid product is reduced simply to the slender tube of lymph cells, the inner layer of which proliferate and produce pus-cells, just as a layer of epithelium would.

Perhaps a still more striking example of this condition of things may be found in the formation of a perineal fistula. Generally there is here a well-developed abscess, with all the usual local phenomena. When this breaks or is opened, the swelling goes down in a surprisingly short time, and the sinus becomes established, just as in the other case. But here there is apt to be rather more irritation than in fistula in ano, on account of the passage of the urine being more frequent and more stimulating than that of the feces, while the parts are more movable and more sensitive.

Equally striking, and unfortunately of late years

even more common under the observation of most of us, are those cases of gunshot wounds in which the presence of foreign bodies or of dead bone gives rise to the formation of sinuses, sometimes long and tortuous. The walls of these sinuses are often so tough and firm as to defy the distending force of the finger pushed along them; and from them there takes place a continual weeping of a purulent liquid, in which, indeed, from the dense and fully-formed character of the elements generating it, the pus-corpuscle is but scantily developed. Any one unfamiliar with anatomy would perhaps scarcely believe that a firm, smooth, apparently well organized and permanent tube such as so often constitutes one of these sinuses could be wholly adventitious and temporary.

But the final overthrow of the doctrine that there is such a thing as a special pyogenic membrane is derived from microscopic observation, which shows that what has been so denominated differs in no respect from other deposits of lymph which have by the force of circumstances been maintained and brought to the state of fully-developed connective tissue. Thus the wall of a sinus contains exactly the same elements, similarly arranged, as an adhesion between the two surfaces of the pleura.

It seems to me that the present is the most appropriate point at which to take up the study of ulceration and granulation; two processes which could hardly be omitted in any discussion of the general subject of inflammation. What I shall have to say about them, however, will be rather in the way of

applying principles already laid down, than of taking them up separately as constituting special and peculiar modes of morbid action.

To begin then with ulceration. I think it may be regarded as always the result either of injury or of a failure of nutrition; often these causes are combined. Perhaps I need hardly mention that Hunter described the "ulcerative inflammation" as a special form, side by side with the "suppurative," the "adhesive," and the "sphacelous." And you are probably all aware that in most works on surgery, ulcers are made the subject of a separate chapter, and divided into various classes, such as the simple, irritable, and indolent,—the simple and specific,—the healthy and unhealthy. Clinically, it may be well enough to employ such terms; but they cannot be looked upon as scientifically correct. The process of ulceration I believe to be always and everywhere the same, but to present in different cases different features, by reason of surrounding circumstances, chief among which are the state of the constitution, and the anatomical structure of the part which is the seat of the disorder.

Ulceration is a step beyond mere abrasion. The limits between them are not always clearly defined; as some of you are aware, it has been within the last few years a subject of active controversy whether in cases of so-called uterine disease there is or is not ulceration of the visible part of the womb. Such a point would seem to be easily enough determined by actual observation, but the fact is that what some physicians call ulcerations, are in the opinion of others abrasions only.

We need not, however, concern ourselves now with these doubtful cases—especially as their clinical history shows that the local disorder, if it be indeed the starting-point of the trouble, is soon merged altogether in the host of other and more urgent symptoms presented.

Ulceration, as I have remarked, seems to be always the result either of injury or of a failure of nutrition, or of both these conditions combined. When a piece of skin is sliced off with a cutting instrument, a sore is left which in everything but its origin resembles the so-called simple or healthy ulcer. Such a wound, if produced upon a healthy and well-nourished person, will tend at once, or at any rate as soon as the first accession of inflammation subsides, to heal up. And so also will an ulcer, if placed in altogether similar conditions. On the other hand, if the general health be undermined, a previously cicatrizing wound will cease to contract, and assume the character usually ascribed to an ulcer.

There are two cases which may be taken as typical of ulceration. The first is that of a bedsore, in which by constant pressure the nutrition of a certain portion of skin is to such an extent interfered with, and its texture so mechanically injured, that it inflames, and sometimes after a very short time, breaks down; so that where there was healthy and sound skin, covered by epidermis, there is a raw and suppurating surface.

The other case is that of a common sore leg, such as may be seen in all the phases of its existence in any almshouse. Here, although very often a blow,

or the rubbing of a boot-leg on the shin, is mentioned by the patient as having originated the disease, the cause alleged is usually insufficient to account for the size and depth of the ulcer when it comes under observation. Sometimes no such cause is assigned; the patient has simply found the skin broken, and the sore has continued to enlarge more or less rapidly. But here we always find the tissues of the part relaxed and flabby, and almost invariably there are evidences of a sluggish circulation in the swollen and tortuous veins.

Now there is a very strong analogy between these two cases in the anatomy of the parts concerned; that is, between the portions of skin over the prominent bony points in the back, over the trochanters, or over the heel, and that which covers the tibia. In neither is there much of a vascular supply except at the periphery, and in both, therefore, the nutrition is readily impaired. And this fact alone shows why, upon the infliction of any mechanical injury, there should be not only a marked effect in the way of inflammation at the point itself, but a tendency in the surrounding tissues to yield to the disturbance, as well as to the mere strain upon them; thus giving rise to an ulcer.

In further illustration of this, take the opposite case of a portion of tissue such as the skin of the cheek, having an abundant vascular supply, and closely attached to the subjacent parts; I think it is obvious that if the same amount of injury, whether by a blow or by mere pressure, were inflicted here, the structures in the neighborhood would be, both

by reason of their better nutrition and of their more efficient mechanical support, less likely to undergo ulceration, which in fact very seldom occurs at such points.

And either by mechanical injury, be it by actual violence or by wearing away, or by failure of nutrition, the loss of substance which gives rise to an ulcer may always be accounted for. Obviously, if the part is put in favorable conditions, the loss will be repaired; if not, the ulcer will remain.

The point at which I wish to arrive is, that neither the origin of an ulcer, nor its spreading, is due to any mysterious power or tendency residing in the tissues. An ulcer is a negative affair altogether—the elements at a certain point on the surface lose their vitality as such, by reason of a failure in the conditions needful for their nutrition. It amounts to the same thing, be the cause of the failure mechanical, chemical, or vital.

Now, let us inquire, what is the anatomy of an ulcer? In the first place, the epidermis, or in a mucous membrane the epithelium, must be wholly gone—and the tissues beneath would be exposed, if it were not that under such circumstances they undergo formative irritation, and their cells by proliferation produce a layer, perhaps a great many layers, of lymph-cells. In a sloughing ulcer this will be apt not to occur, because the formative force of the tissue-elements is lost, as indeed is implied in the fact of their mortification. Hence when the slough in such a case is thoroughly cut away, we come down to muscle, nerve, etc. But occasionally, even in gangrenous ulcers, there is an abundant for-

mation of lymph, the outer layers of which, however, undergo the process of death and putrefaction almost as soon as they acquire their organization.

Now in any case an ulcer must be either spreading, stationary, or healing. The rationale of its spreading has been already set forth. If it remains stationary, it does so simply because the conditions needed for its healing are not present. Let these conditions be furnished, and it will be utterly impossible for the ulcer to do anything but heal. This process is accomplished by means of what is commonly known under the name of granulation. It is entirely analogous, in my opinion, with the other developments of adventitious tissues in the body, and is accomplished by the same means. I must, however, defer its detailed consideration until my next lecture.

LECTURE IX.

GRANULATIONS—CHARACTER OF IN A HEALING SORE—ANALOGY WITH FORMATIONS OF LYMPH ELSEWHERE — FÖRSTER'S DESCRIPTION — ANALOGY BETWEEN AN ULCER AND AN ABSCESS—MODE OF HEALING OF AN ULCER—EVERY STEP OF THE PROCESS DUE TO IMMEDIATE CAUSES — CICATRIZATION — MODIFICATIONS OF INFLAMMATION BY STRUCTURE OF PARTS — PARENCHYMATOUS TISSUES — MUCOUS AND SEROUS MEMBRANES.

At the close of my last lecture, gentlemen, I was about to take up the subject of granulations. We had studied the natural history of the two products of inflammation, lymph and pus, and had then considered in a general way the process of ulceration. Now it may have seemed as if this latter topic had been dealt with too summarily, or at least as if the importance always assigned to it in surgical writings should bespeak for it more extended notice. But in fact we have not yet done with it. The points which had engaged our attention were, the causation and the anatomy of ulcers; and I had stated, that the subsequent course of any such sore must be either to spread, to remain stationary, or to heal. Should it spread, it must be either by the continued action or the extension of the prime cause of the lesion; should it remain stationary, it must be simply because there are not present the conditions which would favor its healing. But if it should heal, it

must be by means of the process which we have now to study—by granulation.

An ulcer once established, that is, the tissues constituting a cutaneous or a mucous surface being destroyed to a certain extent and depth, there will ensue, by reason of the formative irritation of the exposed organic elements, a proliferation of those elements, with the result of covering them with a layer of new, young cells,—or in other words, with a layer of lymph. This lymph will in almost every instance become developed into a permanent relation with the parts beneath, unless, indeed, the circumstances are so unfavorable that it either sloughs or degenerates into pus, in which case the ulcer is still further deepened.

Under the best auspices, however, this organized layer of lymph will enter into permanent relationship with the subjacent tissue, and its cells will then undergo a like proliferation, giving rise to another layer, and so on. What very often happens, again, is that this process of building up goes on well for a time, and then becomes checked. It is at this stage of affairs that ulcers usually come under the eye of the surgeon. In other words, the ordinary anatomy of an ulcer is as follows: a gap in the surface-tissue is partly filled up by a deposit of organized lymph, so that we have a cavity of greater or less depth, bounded everywhere by this adventitious substance. Sometimes the deposit is so abundant as to bulge up and constitute what is called a fungous growth, so that instead of a cavity there is a protrusion; of which one of the best instances may be seen in what is known as the toe-nail ulcer.

Perhaps I need scarcely state that this exuberant formation of lymph does not indicate an excess of organizing force, but rather the contrary. The granulations which spring from healthy and well-nourished tissues are florid, smooth, and firm, and tend to become quickly conformed in general shape, as nearly as may be, to the normal type of the part. Often the superabundant granulations are pale, flabby, and irregular, and bleed at the slightest touch. Such a mass, looking very much like the lymph which is apt to be found infiltrating the areolar spaces of limbs affected with degenerative disease, may very commonly be seen occupying the space between the edges of ill-conditioned stumps. It is in fact due to precisely the same causes. The elements to whose proliferation the lymph-cells are owing, are stimulated to excess, but are at the same time weakened; they originate new cells quickly, but this very fact prevents those new cells from establishing themselves in such relations with the progenitive tissues as are necessary to their permanent development. Hence, in such a state of affairs, we see just what we might have expected; an abundance of new elements, remaining in this state of youth because the circumstances under which they are placed do not favor their becoming mature.

And here I may say what I omitted in speaking of the ultimate development of lymph, that such a transition from the status of young, crude cells to that of fully-formed connective tissue, and certainly the further change undergone by some of the cells into epithelium, cannot occur so long as the inflam-

matory process continues. It is only when the abnormal stimulus ceases to act, and the part returns as nearly as possible to its healthy condition, that this elaboration of the adventitious substance begins.

No very deep knowledge of anatomy is needed to enable one to affirm that nothing like the crude and undeveloped lymph just alluded to belongs anywhere in the healthy body. The replacement of such cells as become effete, the generation of such as are needed by any fresh stress upon a part, takes place without any palpable accumulation of masses of the as yet unclassified elements, if we may so call them. But when an agency of such a character and energy as to excite inflammation is brought to bear upon a part, the formative irritation which ensues is exhibited in this very way, by the rapid production of young cells, which may either remain in their primary condition as lymph, or become converted into the degenerative elements of pus.

If I may be allowed the comparison, not in every respect complete, the excitement which raises up large bodies of raw recruits must in a great measure subside, and give place to a steady determination and a rigid discipline, if the result is to be the organization of an efficient army.

To return then to the formation of granulations. It is carried on, I maintain, in the same way as that of adhesions or similar deposits of lymph; or rather, it is the self-same process, presenting a different aspect because going on in a different situation. And, as was argued in relation to the mode of establishment of the vascular supply in such cases, the vascularization of the lymph which goes to make

up granulations is due to the attraction of the elements of that lymph for the blood contained in the neighboring capillaries.

The anatomy of the structures so built up has been most admirably described by Förster, a recent German writer, as follows:

"They have always the relation of products of inflammation to the tissues and organs from which they arise, and from these their elements are in part formed; these elements are: vessels, mainly capillaries, connective tissue more or less fully developed, and cells having the general character of pus-cells. The mode of formation and histological relations of granulations are best shown by examining them in some of those organs in which they are most commonly presented.

"We find granulations oftenest at the bottom and edges of ulcers in the skin; they form here very numerous, red, rounded elevations, varying in size from that of a millet seed to that of a pea, sometimes larger and more prominent granular masses. Now how do these formations arise from the normal tissue-elements? by what processes is this latter deprived of its proper texture and converted into such granulations? If we make thin perpendicular sections through the tissues at the edge of an ulcer of the skin, which is increasing outwards, and at the edges of which within a few days normal skin has been changed into granulations; and put these sections under the microscope, we see as follows: In passing from the healthy parts towards those which are altered, we see the most remarkable changes in the vessels of the papillæ; the capillaries which run up into and down out of the papillæ, become wider and longer, and seem to become more tortuous than usual. Then the tortuosities become more numerous and larger, and run into one another almost perpendicularly, until at last the papilla becomes filled with a tangle of such windings, too intricate to be distinguished by the eye; since all the capillaries are equally distended with blood, they come out very markedly in such preparations. While this alteration goes on in the vessels, the connective tissue of the papilla likewise grows, and increases in breadth; the several papillæ come nearer

together, and since at the same time the skin itself becomes swollen, their bases widen, and they become as it were fused by degrees into one another. The connective tissue of the skin and of the papillæ thus becomes more homogeneous, softer, and the nuclei of the connective-tissue corpuscles show more clearly than they previously did; while in the vessels of the skin the same changes in shape and calibre take place as were before mentioned in those of the papillæ. The epidermis shares at the same time in the alteration, in that the cells of the mucous layer increase in number, and this seems enlarged, and like all the other tissues softer and more delicate. The nearer we come to the edge of the ulcer, the more marked are all these changes, until the papillæ and the corium are blended into a mass, in which only above, at the free edge, can any trace of indentations be detected; their substance has become extremely soft, the connective tissue homogeneous, and interspersed with longish nuclei and spindle-formed cells in greater or less number, but especially with pus-cells. The capillaries run up out of the cutis and spread themselves out above in numerous windings; it is evident that the granular character of the surface is due to these numerous capillary loops pressing their way toward the exterior. The capillaries of the different papillæ are now crowded closely together, and as it would seem, are also united by anastomoses. The cells of the mucous layer become gradually replaced by pus-cells, and those of the horny layer pushed off entirely, so that the conversion of this portion of the cutis into a granulation is completed."

The excellence of this description seems to me the best apology, if any is needed, for so lengthy a quotation.

Now the great rapidity with which pus is formed upon granulating surfaces can be readily accounted for when their anatomy and mode of construction is once understood. Here is going on an abundant generation of new cells; they are crowded together, and while some acquire a settled relation to one another and to the blood-vessels, others, and these

a very large proportion of the whole number formed, are unable, as it were, to gain a foothold, and take on the lower and degenerative character of pus-corpuscles. It needs scarcely perhaps to be mentioned that there is a striking analogy between this condition of things and that which obtains in an abscess, as already described. The only difference lies in the fact that in the latter case the granulations and the pus are in the cavity of a hollow sphere, from which the air is excluded, while in the ulcer they are on a surface, theoretically if not actually hollowed out.

This is a true histological substitution. When we wipe off a drop of pus from the surface of a granulating sore, and put it under the microscope, we are looking at millions of cells, every one of which, under favoring external circumstances, would have assumed a permanent place in the economy. And when we examine a thin section of a mass of granulations, we are looking at hundreds of cells, every one of which, had it not met with a suitable opportunity for settling, if I may so speak, would have lost all of organization but the form, and as a pus-cell become practically effete.

Moreover, we find in the circumstances of the case a perfectly simple explanation of the difference between the organization of a mass of lymph effused, for instance, between two serous surfaces, and that of a mass of lymph developed in an ulcerated patch of skin. In the former case the vessels are in very small proportion to the quantity of lymph, in the latter case they are abundant. In the former case there is a very long distance between many of the

lymph-corpuscles and the capillaries, in the latter case a very short one. In the former case the innervation which, as is universally conceded, is necessary for organization and nutrition, is obviously more complete and energetic than in the latter. Lastly, it may perhaps be that the great readiness with which, upon a granulating surface, some of the cells may lose their connection and be thrown off, enables those which are not so detached to acquire their status more quickly and completely than they otherwise would.

The position I would take, therefore, in regard to the process of granulation, is that it is wholly analogous to the development of lymph elsewhere into adhesions; the only difference between the two cases lying in the incidental circumstances under which the adventitious elements are placed.

In order to complete the application of the principles laid down in earlier portions of this course of lectures, allow me here to digress for a few moments, and to speak of the method in which the healing of an ulcer is perfected.

I have several times had occasion to bring forward the idea that there is for every class of animals, for every individual of each class, and for every unit of organization, a certain programme to which it is ordained to conform, as well as a certain anatomical type. And it must be evident that the occurrence of ulceration, from whatever cause, is a departure from this type, so far as the affected part is concerned. The observations of Paget and others show, that if portions of crystals are broken off, and they are then placed in favorable conditions, they tend

to repair their loss, and to assume again their normal shape. It can hardly be supposed that a single cell, if so injured, could fail to lose its life altogether. But of a mass of cells forming an organ, we know that it is otherwise. We know that the development of new cells fills up, for example, the cavity left by an ulcer or a wound.

On the other hand, however, we have abundant instances in which the approach to the normal anatomical type is lamentably incomplete, as in the faulty cicatrization of burns. If there were presiding over every process of repair that mysterious sanative agency spoken of as nature, it is surely strange that she should be so careless as not to forestall the mischief which so often ensues in such cases.

What I would again insist upon is, that from first to last the changes which take place in matter, organized or unorganized, are due to the immediate operation of surrounding circumstances—so that the formation and modelling of an adhesion between two serous surfaces, of the cicatrix of a burn, or of that of a common ulcer of the leg, constitute one and the same process, and obey the same laws.

Hence, when the granulations which fill up the cavity of an ulcer cease to be stimulated to further proliferation, those which lie at the edges of the sore no longer generate pus-cells; they become dry, and gradually acquire the same relation to those below them that the epidermis has in the unbroken skin. They become also insensitive to the irritation of the atmosphere, as the epidermis is. How far they assume a resemblance to the cuticle, in their

minute anatomy, I cannot say. Just so far as they are subjected to influences which favor their developmental changes, they will be developed, and no farther. It would be just as easy, and in my opinion just as rational, to suppose that striated muscular fibre might be formed on the surface of a cicatrix, as that regular epidermal cells may be.

If these statements be correct, we must lay aside altogether the idea that when a loss of substance occurs in any organ, there is a deliberate attempt, on the part of the neighboring tissues, the organ itself as such, or the economy, to replace what is gone, and to restore the normal shape. In any such case, the adjoining cells undergo formative irritation; they proliferate, some of their progeny becoming permanent in the animal, others being thrown off as pus. Those which become permanent assume the character, generally, of connective tissue, some of them probably becoming in a measure allied to epithelium or epidermis.

It does not seem to me that in such a view of the process of repair of injuries there is involved anything like a slighting or a want of recognition of the Divine power in the regulation of the material world. It would be an undeniable miracle if, after the amputation of a thigh, or even of a finger, the lost part should be reproduced; and if there were but a clumsy attempt at such restoration, it would be no less a miracle, if we can conceive, with due reverence be it said, of a badly performed miracle. And yet there is no middle ground; if there is ever a deliberate effort at reconstruction of a portion of any organ which is destroyed, then there should be

a possibility, at least, of the re-formation of an entire limb. Certainly it is more in accordance with all else that is known of natural processes, to trace the working of one general, simple law, which makes the production of lymph the result of formative irritation, responded to blindly and of necessity by the tissues.

In the clear and beautiful exposition of the subject of the restoration of lost parts in some of the lowest living forms, with which Paget introduces the discussion of the repair of injuries, he shows plainly that in all such cases the new structures are merely aggregations of elements analogous to connective tissue, and that the power of producing them is in inverse ratio to the amount of power consumed in the development and growth of the individual, and in its maintenance in the perfect state.

He further says that—

"In man and other mammalia, a true reproduction after loss or injury seems limited to three classes of parts: 1. To those which are formed entirely by nutritive repetition, such as the blood and epithelia. 2. To those which are of lowest organization, and (which seems of more importance) of lowest chemical character; as the gelatinous tissues, the cellular and tendinous, and the bones. 3. To those which are inserted in other tissues, not as essential to their structure, but as accessories, as connecting or incorporating them with the other structures of vegetative or animal life; such as nerve-fibres and blood-vessels.

"With these exceptions, injuries or losses in the human body are capable of no more than repair, in its most limited sense; *i.e.*, in the place of what is lost, some lowly organized tissue is formed, which fills up the breach, and suffices for the maintenance of a less perfect life."*

* Surgical Pathology, p. 115. (Am. ed., 1854.)

The general law, then, which seems to me to have been developed in the foregoing discussion, is that the alteration in a tissue which we call inflammation consists, in part, of a stimulation to the elements of such a tissue, by reason of which they proliferate or give rise to new cells. And the cells produced under this law may go on to a development in connection with their parent textures, influenced entirely by surrounding circumstances, so as to incidentally effect such repair as they may. Incidentally, altogether; for the process by which the two layers of the pleura become bound together by organized and living tissue, which in its subsequent completion contracts so as to draw in and deform the side of the thorax, is in all its essentials the very same with that by which the ravages of a burn are repaired, with the frightful disfigurement so apt to attend its latter stages.

Let me here go back for a moment to explain one point. In the quotation which I just now made from Paget, it was said that the accessories of other structures, such as vessels or nerve-fibres, might be reproduced; and the inference might perhaps seem to be a just one, that if such parts might be reproduced, they might also be generated de novo. Such however is not the case. Cut out a small portion, say the one-eighth or the quarter of an inch, of a nerve, and the lymph-cells deposited in the gap may assume the functions, if not the physical characters, of the lost elements; but it is obvious that this is quite a different affair from the sprouting of a new nerve-filament into a granulation. And so also of vessels.

There is one point in connection with the establishment of cicatrices in ulcers, which have healed by granulation, which has never been so far as I know satisfactorily explained; it is the way in which the very soft, florid, and vascular substance of the granulations becomes converted into the firm, pale, and apparently non-vascular fibrous tissue of the permanent healing medium. But upon the views I have stated in regard to the original mode of origin of the vessels in such a new structure, it seems to me that their disappearance may be accounted for without difficulty. The new elements acquire characters, both gross and microscopical, closely allied to those of ordinary connective tissue; their nutrition no longer goes on so actively as before, for proliferation has ceased, and the rapidity of interchange between the elements and the blood is always greater during development than in maturity. Hence the supply of blood which in the former stage of the construction was no more than adequate, would in the latter be altogether excessive. There is therefore a diminished attraction exerted by the new-formed tissues upon the blood —the current in the vessels slacks, and the shrinking of the lymph-corpuscles into fibres tends to narrow the channels by which the blood finds its way between them. And when the so-called structureless character of the capillaries is remembered, it can easily be seen that their closure would simply rank them with the amorphous intercellular substance which exists in so many of the simpler tissues.

We have now, gentlemen, gone over the whole of the natural history of inflammation, inquiring into its phenomena and their causes, local and general, its modes of termination, and its incidental effects in the formation of lymph and pus. It remains for us to study the modifications impressed upon the disease by the varieties of structure in the tissues which form its seat. That such modifications exist, is a matter of constant observation in medical and surgical practice — and the misapprehension of them has given rise to many mistakes in pathology. I think that a careful study of them will show that they are non-essential.

Upon a strictly anatomical view, we find three great structural classes, under which the constituents of the body may be ranged. Mentioned in the order of their seeming importance, these are (1) the parenchymata, (2) the mucous membranes, (3) the serous membranes.

Under the first of these classes are included brain and nerve-tissue, *the blood*, blood-gland-tissue, muscle-tissue, and the mechanical structures, — bone, cartilage, and connective tissue. This latter item is obviously of great importance, embracing as it does the outer and middle coats of all the vessels, down to the mere capillaries, and the framework in which all the special organs are imbedded.

The mucous membranes comprise the pulmonary, alimentary, genito-urinary, mammary, and auditory epithelial linings, as well as the skin, which is continuous with them all. Moreover, to several of these must be added glandular appendages, or follicular offshoots.

The serous membranes, or shut sacs, include the peritoneum, pleura, pericardium, lining membrane of the entire vascular and lymphatic system of vessels, cerebro-spinal arachnoid, tunica vaginalis testis, joint-cavities, and bursæ.

Perhaps it would be more strictly correct to make only two classes, the parenchymatous and the membranous or epithelial—the former including all those organs whose mass, uniform and persistent in its elements, is endowed with a function peculiar and special to itself—while the latter comprises those which form surfaces—which depend on the accident of their situation for their function. Each cell is like all the rest, and any one, if it could be wholly isolated and yet supplied with nutritive material and the other conditions of its life, would either fulfil or be capable of fulfilling its function. Such is the case with the constituents of bone, cartilage, tendon, both kinds of muscle, connective tissue, all the special gland-structures, and all the parts of the nervous system. Whatever the function of these elements, it is intrinsic—the mechanical tissues, as bone, cartilage, tendon, muscle, and connective tissue, are resistent or contractile in themselves, and not by virtue of any accidental position in which they may be found—the gland-cells, of the liver, kidney, etc. stand in a special relation to the blood, be that relation considered as merely chemical, or as a vital and mysterious one. Above all, the nervous system, the attribute of the higher organisms only, more complex and more fully developed according to the rank of its possessor in the scale of being, and culminating in man as the exponent of

the soul, is composed of special tissues, the elements of which are indeed mutually dependent, but which are as peculiar in structure as in function.

I know of no reason why to the list above given there should not be added the blood-mass, as a special organ with a universal relation to the tissues. It has several functions, like some of the other special or parenchymatous tissues—the most prominent being the carrying of nutriment and of oxygen to the other tissues—and depends like them upon a supply from without for its life.

Now when we come to examine the membranous systems, we find that while their essential structure is the same throughout, a vascular network interlaced with connective tissue, in relation with a surface coated with epithelium, some of them communicate by continuity with the external surface, while others are shut sacs—and as this difference of arrangement corresponds with some differences in both the normal and the abnormal processes which take place in these structures, we may make the further division into mucous and serous membranes.

In the mucous membranes we find the epithelial layer thicker than that of the serous, and composed of many more strata. It is thrown off continually, more or less rapidly in different parts, and mingled with the detached epithelium are found, on the internal membranes, certain corpuscles known as mucus corpuscles.

Beneath the epithelial layer we find a mass of connective tissue imbedding the vessels; it is in general thicker and softer than that underlying the epithelium of the serous membranes.

The mucous membranes embrace, besides the skin, the alimento-pulmonary, genito-urinary, and auditory.

In the serous membranes we find a thin, firm, persistent layer of epithelium, overlying a comparatively thin subserous stratum of connective tissue. Their secretion is a clear, viscid liquid, in some of them so small in amount in health as to be a mere exhalation, in others much more abundant. The anatomical structure is in the mucous membranes in a state of evolution, in the serous in a state of involution.

Now it will be easily seen that the parenchymatous textures and the mucous membranes are often in close relation with one another; as is the case for instance with the proper gland-tissue of a salivary gland and its ducts. The two are more distinct in the case of the liver than in that of any other gland.

Now although the essentials of the process of nutrition are exactly the same in all these classes, the arrangement of the tissue-elements in each, and their relation to the vessels, are peculiar. In the first class, which I have called the parenchymatous, the cells or fibres as the case may be, are massed together, and the vessels of supply are carried through those masses so as to form a network.

It is upon these differences of arrangement, which are non-essential, that the differences in nutrition, which are also non-essential, depend. And it is but a step further to say, that if the nutrition be disturbed, as in inflammation, we might naturally expect to find that the results of such disturbance pre-

sented even wider and more apparent differences than the normal state of things. To take the most obvious instance, at the first glance there would seem to be a radical distinction between a boil and an inflammation of the pericardium. But on a closer scrutiny it becomes evident that there is in each case redness, heat, swelling, pain, and disorder of function. Moreover, there is in each case a formation of adventitious elements,—of lymph corpuscles and fibrillæ. And by pursuing the only rational mode of inquiry in natural science,—by following up the successive shades of difference, we establish a chain of gradations between these two extremes, and bring them both under the same law as regards their normal as well as their abnormal conditions.

The process of inflammation can take place only in the substance of tissues, since it is here only that there exists a nutrition to be deranged. And hence, in the case for example of the skin, or of a mucous or serous membrane, the actual seat of the disorder must be in the subcutaneous, or submucous, or subserous layer of connective tissue, in which the nutrition is carried on.

But although no objection be made to the statement that the essence of inflammation is theoretically the same in all these cases, and that in fact it is seated in analogous structures, the course and effects of the disease are in appearance widely different; and this fact gives color to the idea so generally held that there is in mucous membranes, for instance, an inherent tendency to form pus or to ulcerate, while the serous membranes are in some

mysterious way inclined to throw out lymph, as the expression is, and to form adhesions between their opposed surfaces.

If the description given of the phenomena and effects of inflammation be recalled, it will be evident that they are exhibited most clearly in the parenchymatous tissues, among which may be included the proper texture of the skin. In the mucous membranes, and especially in the thinner ones, the readiness with which disorder of the secretions, whether in the way of excess or of changed character, takes place, is apt somewhat to mask some of the features of the primary disease. On the other hand, in the serous membranes or shut sacs, the tendency is to the copious pouring out, within the cavity, of a liquid possessing such characters as indicate its inflammatory origin. In both these latter cases, the deposition of lymph, although it occurs in the submucous or subserous connective tissue, is very apt to be overlooked, from its relatively small quantity.

I think, however, that I am safe in saying that if you put a mucous membrane into the condition of a serous membrane, or the converse, you will inevitably find that they will no longer differ in the manner just mentioned. Let us reduce this abstract statement to the concrete.

In the vaginal mucous membrane we have, upon a basis of connective tissue, layer upon layer of epithelial cells. The constant succession of these cells, and the accumulation and flowing off of mucus and of the discharges from the uterus, must obviously prevent anything like adhesion between the opposed

surfaces in the normal state of affairs. And when inflammation occurs, the abundant proliferation of the epithelial cells, giving rise to pus or to large quantities of mucus, will generally have the same effect.

In the pleura, a perfect serous membrane, the connective tissue which forms its basis is less abundant, and there is only a thin layer of closely attached epithelial cells on the surface. When inflammation takes place, the formation of lymph readily occurs, and the deposit, like the cells generating it, has no chance of being thrown off; it is therefore placed under circumstances highly favorable to its continuance, and to its assumption of a permanent connection with the surface whence it came. If from the state of the blood, or from the character of the local disturbance, the lymph formed is of poor quality, or if the access of air to the cavity of the pleura is added to the other causes of irritation, the adventitious elements may break down into pus, and the pleurisy becomes an empyema.

Now if any portion of the mucous membrane loses a great part, or the whole, of its epithelial covering, and if, moreover, the discharges cease to flow so as to keep the sides of the passage, thus denuded, separate, there will ensue as firm a union as would be possible between the costal and the pulmonary pleuræ. For in fact, the special conditions of the mucous membrane are done away with, and it comes to resemble a serous membrane.

And conversely, if, as often happens in the case of empyema, the deposit of lymph on the pleural surface is thick, and tends to break down continually into pus, the anatomical peculiarity which distin-

guishes the serous membrane no longer exists, and there is no longer the special tendency to the formation of adhesions which previously pertained to it.

I believe, but I have not had an opportunity of investigating the point with reference to our present inquiry, that sections of inflamed serous and mucous membrane would show that, in the one case as well as in the other, there was a proliferation of the connective-tissue cells about the vessels, or in the language usually held, a deposit of lymph, alike in the subserous and in the submucous tissue. And as to that which is superficial, the circumstances under which the newly-formed cells in the mucous membrane are placed are such as to favor their degenerative change into pus.

A sort of neutral ground between these two extremes is found in the parenchymatous tissues, such as the glandular or muscular, or the connective where it exists in quantity. Here an inflammation will give rise to the formation of lymph, which may become organized into a permanent relation with the original structures, just exactly as that which constitutes a pleuritic adhesion does, or which may break down into pus and be discharged, as that would be which had its descent from the epithelial cells of a mucous membrane.

I think, therefore, we may state that in the first planning out of the living organism, the simple laws of structure and nutrition were laid down; and that when nutrition is disturbed by the excitement of inflammation, the course of the disease in any part conforms as far as it may, or rather corresponds, to the normal order of things. This view seems to me

far more rational, and much more in accordance with the idea of an all-wise Creator, than the supposition that, disease being inevitable, a special provision was made by which it should be productive of the least possible degree of harm, or its ravages repaired.

LECTURE X.

THE THERAPEUTICS OF INFLAMMATION—GENERAL RELATIONS OF PATHOLOGY AND THERAPEUTICS—INFLAMMATION ALWAYS CALLS FOR TREATMENT—OBJECT OF THIS, TO RESTORE NORMAL CONDITIONS OF NUTRITION—VARIOUS WAYS OF ATTAINING THIS OBJECT—EFFECTS OF COLD—OF WARMTH AND MOISTURE—OF COUNTER-IRRITANTS—OF GENERAL BLEEDING—OF DERIVATIVES—OF LOW DIET—OF ANODYNES—OF ASTRINGENTS—OF ALTERATIVES—THE ESSENTIAL AIM IN ALL THESE CASES THE SAME—CONCLUSION.

THE subject, gentlemen, with which I propose to occupy your attention in this, the concluding lecture of my course, is that of the therapeutics of inflammation. It is not, however, my design to give you a mere catalogue of the remedies to be employed in this disease, and their modes of application, since you are probably familiar with all this from other sources. What I wish to do is to test the views which I have advanced in former lectures, by the results of treatment. For we may be sure that pathological theories are wrong, which are at variance with such results.

Pathology is and must be subordinate to therapeutics; subordinate as an object, but superior as a science. In fact, it would be more correct to say that the former is a science, the latter an art based upon it. All medical knowledge is useful just so far as it enables us to prevent or to cure disease. Just so far as disease is a mystery to us, our treat-

ment of it is empirical; and the more thorough our comprehension of its phenomena and their causes, the more directly and intelligently can we undertake its prevention or its cure. On the other hand, a due appreciation of the value and mode of action of remedies cannot but throw light upon the conditions against which they are employed.

According to the popular idea, a disease is an entity, which, as the phrase goes, gets into the system or into a part; and we send in a medicine to extract or neutralize it. Thus it is often said, that "the inflammation is drawn out" of a part, as for example by leeches or by a poultice. It is probable that the idea implied in this expression is often unconsciously entertained by physicians; and in regard to some diseases, as for instance syphilis, there can be no doubt that such a theory not only prevails, but would be assigned as the basis of sound and successful modes of practice. Thus it is often asserted that iodide of potassium is a specific for syphilis, and hence that it neutralizes the poison, whatever that may be, which exists in the blood. Here, however, we are in the region of avowed empiricism; we know from experience that many cases of syphilis have been benefited by the use of the iodide, and are encouraged to administer it to other patients similarly affected. But the happy results of the practice do not by any means substantiate the theory. The history of medicine shows many instances in which empiricism has been set aside by empiricism, as for example when Ambrose Paré was compelled to forego the use of boiling oil in some cases of gunshot wound, and discovered to his

amazement that the belief in the necessity of such applications was without foundation. And the progress made through empiricism has sometimes been rendered positive and permanent by the advance of scientific pathology, as in the instance just adduced. But there are diseases, such as the malarial fevers, which still remain inexplicable, although we treat them empirically with success. The fact is that the empiricism is only in less degree in one case than in another; or at least it seems as if in one the chain of causes and effects were shorter and more easily traced than in the other.

Now it may be that many of the remedies in common use in the treatment of inflammation are so employed upon the ground of experience only; or at least that, being proved by experience to be of value, the theory of their action is either incorrect or inadequate. Let us see whether we can put those modes of treatment on a scientific basis, and at the same time whether in this attempt we can derive any further light upon the points formerly discussed.

The object of all therapeutics must be, either directly or indirectly, to convert the abnormal state of things into the normal, as nearly as possible. Sometimes chemical agents answer this purpose; as when the stomach is irritated by the presence of acid matters, and we put an alkali into it to neutralize the acid. Sometimes mechanical support is needed, as when a broken bone no longer serves as a stay for the surrounding soft textures. When an amputation is in any way rendered necessary, it is upon the same principle. The crushed or diseased limb is in a state of irreparable abnormity, which

involves disturbance to the entire organism; and the surgeon simply removes the affected part in such a way that the stump shall be as quickly and as thoroughly healed as possible. The very word therapeutics, or healing, implies the making whole, or healthy, or normal.

It is sometimes the case that medicine, more frequently that surgery, aims directly at the removal of an offending cause. Sometimes, on the other hand, we must direct our efforts to the counteraction of its effects. And there are many instances, especially in medical practice, in which the chain of conditions intermediate between the cause and its palpable effects, as well as between the remedy and its resulting benefit, is long and intricate. Of this latter statement striking illustrations may be found in abundance among diseases of the kidneys.

Now you will remember that one of my earliest assertions in regard to inflammation was that it constituted, always and everywhere, a disease. And hence it always calls for treatment. If for any purpose the surgeon excites it, as a less evil than some pre-existing abnormal state, he looks upon it as a temporary condition only. We never think of establishing an inflamed state of any portion of the skin as a permanence in the economy. A blister, a seton or an issue may be kept up for a time, but as soon as its beneficial effect is fully secured, measures are taken to heal it. Often, indeed, the mere removal of the artificial irritant suffices, and the tissues affected by it subside into their natural state.

And when we consider the relation of inflammation to other diseases, we see that our therapeutics

are directed very much by it. In some cases this relation is one of cause and effect; the inflammation is allayed, and all the symptoms disappear. Or the inflamed state of an organ or set of organs depends on some other abnormity; and then the primary disturbance is the first object of our remedial measures, while we either trust to the removal of this for the consequent subsidence of the inflammation which ensued upon it, or aim at once at the correction of the cause and the alleviation of the effect. But in every case the essential indication is the same, viz.: to restore as far as possible the normal condition of things.

Moreover, the mode of departure from this condition is, as was argued in the earlier lectures of this course, a disturbance of nutrition. So entirely is this view sustained in regard to all those inflammations which can be studied, and so completely does it accord with what is known of the whole process of life, that it may be accepted as of general application. Obviously, therefore, the object of any treatment adopted must be to restore or imitate the normal conditions of nutrition. Hence the regular supply of suitable nourishment, the proper state of the part to be nourished, and an influence of the nervous system of the right kind and degree, must be provided for. It must not be forgotten that there may be too great as well as too small a supply of nutritive material, nor that the part may have a very great power of attraction for the blood without its nutrition being therefore rendered more active.

Another point which was urged in connection

with the subject of normal nutrition and its disturbances was, that the relation between the tissues and the blood is one of the utmost accuracy. Every individual cell must itself be in connection with the due supply of nourishment, and although our dealings are with masses of cells, yet each one of these is concerned in the general result. As a consequence, in any derangement of nutrition the cells composing the affected part must be involved singly as well as collectively; and any curative measures must in like manner influence each as well as all.

Furthermore, as in departing from the healthy state the tissue-elements, like any other collections of material atoms, blindly obeyed the forces brought to bear upon them, so in returning to it they are wholly passive. They have no tendency to resume their normal status. Being subjected to causes of derangement, the sum of their combinations is abnormal—those causes ceasing to act, or being overbalanced by opposing forces, the tissue-elements are again placed under favorable conditions, and obey them.

It is therefore evident, not only that the aim of all therapeutical procedures in cases of inflammation must be to restore or imitate the natural condition of things, but that this object may be sought in one or more of several ways. First, we may endeavor either to remove the irritating cause, or to counteract it by sedative agents. Secondly, we may seek to allay the irritation which exists in any mass of cells as the effect of some previous disturbance. Thirdly, we may seek to restore the supply of nutriment to its normal quantity or qual-

ity. Fourthly, we may employ means calculated to correct any existing derangement of innervation.

Now, as will be presently shown, all the tried and approved plans for the treatment of inflammation are such as answer one or more of the objects just enumerated; most of them depend for their efficiency upon several influences which they exert upon the affected parts. And the more completely, in any case, the normal conditions of nutrition are either imitated or restored, the more ready and thorough will be the return of the part to the state of health or freedom from inflammation. The real question which presents itself to the physician or surgeon in determining upon the course to be adopted in any case, is therefore how best to effect such an imitation or restoration of the normal state of things.

Of late years, as many of you well know, there has been a tendency to the substitution of very simple dressings for the complicated formulæ which were previously in vogue. Cold water has been found one of the most efficient of local applications. Under this term may be included also ice, which is the same thing as water at 32° Fahrenheit, since it acts by melting, and so assuming this state.

The fact is well known, that cold is a depressing agent. It is a sedative—diminishing innervation, and acting also directly upon the tissue-elements of any part exposed to it. On analyzing this influence a little further, we shall find, I think, that the modern doctrine of the correlation of forces has a direct bearing upon its explanation. Thus nerve-force, heat, and what for want of a better term I have

called vital force, are mutually convertible. If we lower the temperature of a part, just as when we chill a mass of inorganic matter, we do what in the language of a few years since would be called abstracting heat from it; but what according to the most recent developments of science is merely causing a change in the relation of its atoms. In other words, we convert chemical or mechanical force, or life-action, or electricity, into heat—and as the cold dressing is heated at the expense of the affected part, the latter loses a force amounting to whatever is necessary for this heating.

Tracing the chain of phenomena the other way, we have, as was stated in our discussion of the natural history of inflammation, a rise of temperature, an irritation of the nervous filaments of the part, an increased but deranged innervation, an augmented attractive force exerted by the tissue-elements upon the blood, and in almost every case, —according to some pathologists invariably,—a formative irritation, resulting in the production of the new organisms known as lymph-cells. Here then, according to the principles advanced in explanation of these symptoms, there is a development of chemical force, of electricity or of something closely allied to it, and of vital force. Not that either of these arises *de novo*, but that the force, whatever it is, which constitutes the disturbing cause as such, is converted into these forms.

Now when a cold dressing is applied, the conduction of heat which at once begins, and by which the temperature of that dressing is raised, is owing to the conversion of the forces above named into heat.

The chemical, electrical, and vital forces whose exaltation in the affected part constituted the inflammatory condition, are changed into the heat necessary for the bringing up of the temperature of the dressing. It would be out of place for me here, even if it were in my power, to examine into the nature of heat and the laws of its transmission. The terms which I have used are not yet abandoned, although it may be that others more strictly in accordance with the theories of modern philosophy may before long be substituted for them.

The principle which I have before had occasion to urge, that for every effect there must be an adequate cause, and that for every force there must be an equivalent effect produced, comes in here again. It is no more conceivable that in any case of inflammation there should be a greater amount of heat developed than is exactly equal to the forces expended in producing it, than that under any circumstances two and two should make five. Nor is it possible that the application of cold should destroy any of the forces operating in the tissues which are inflamed. Force and matter are alike convertible, and alike indestructible.

From all that has now been said, we may derive the following statement: In any living organized part, there are certain changes continually affecting the particles composing it, by reason of the mechanical, chemical, and vital forces of which those particles are the agents; if any force acting from without disturbs the mass, it produces an irritation exactly equivalent to itself, becoming converted into vital, chemical or mechanical forces; and by

the application of suitable means these may be again converted into heat, which is further conducted away from the part, to produce an effect exactly equivalent to itself upon matter which does not belong within the organism.

The application of mere cold to an inflamed part, therefore, affords relief in several ways. It is a sedative because it induces a conversion of electrical and vital force, admitting that this latter exists, into heat; it absorbs the force which would constitute an attraction between the tissues and the blood, and that which would bring together the different atoms by chemical affinity into combustion, changing them also into heat. And just as the prime cause of the disease is adequate to its production in a certain degree and extent only, so the remedy applied can give rise to no more than its legitimate effect.

Now in regard to the effects of cold, as also in regard to those of any other remedial agent for the disease in question, it must be remembered that there are certain other modes in which it may influence the part as well as by this mere abstraction, if the phrase may still be used, of heat. For instance, it is a matter of common observation that the involuntary or at least the non-striated muscular fibres contract under its impression, and that as a general law matter diminishes in bulk as its temperature is lowered. And in this way also the impaired conditions of nutrition are rendered more nearly normal. Thus if the skin be involved, the application of cold will lessen the calibre of the smaller arteries, not only by causing their circular fibres to

shorten, but also by the organic muscular fibres of the part being drawn up, so as to compress the channels through which the excessive supply of blood finds its way to the seat of the disturbance.

It can scarcely be needful for me to argue that all the modes in which cold has hitherto been shown to act in reducing inflammation involve also the favoring of a return of the tissue-elements to their normal state. But if this be the case, then the effect of the remedy may be summed up as a restoration of the essentials of nutrition, viz.: of a right state of the parts to be nourished, a due supply of suitable nutriment, and a healthy innervation. So far, therefore, the idea is borne out that inflammation consists in a disorder of nutrition.

Another plan of treatment in this disease, which often proves of great benefit, is that by warmth and moisture. It makes very little difference whether the simple warm-water dressing, or poultices, be chosen, since both act on the same principle. Here the most prominent result is the inducing of free secretion, and the placing of the inflamed part in circumstances analogous to those of its healthy state. The relaxation of tissue which is brought about by a combination of warmth and moisture, and the soothing of irritated nerve-filaments as well as of the irritated cells, together with the absorption of water which probably often takes place, are the main, or at least the most apparent, advantages thus gained.

Every one knows how much less the irritation is, and how much more readily healing takes place,

after subcutaneous operations than when the air is admitted. And in almost all superficial inflammations it may be assumed that the protection afforded from the air, by a bland and non-stimulant dressing, which approaches somewhat in character in this respect to that of a mass of living tissue, must be of no small consequence as favoring the return of the affected part to its natural and healthy state. In deeper-seated inflammations, the advantage derived from poultices or warm-water dressings is probably attributable to the reflex influence upon the nervous system of the parts involved.

And here let me digress for a moment, and anticipate what I shall have to say in regard to counter-irritants. Sometimes, as in pneumonia or pleurisy, we apply a blister to the skin covering the affected part, with good results. Sometimes, on the other hand, we employ a poultice, and find it of advantage. And it may seem as if there were an inconsistency in thus seeking the same end in ways so opposite. But in the one case the irritation of the skin, by exciting the cutaneous nerves, relieves those of the deeper textures; according to the law mentioned in an earlier lecture, by virtue of which there is a balance maintained between one part and another. The stimulation of the skin is very powerful, and outweighs the less severe but more dangerous disorder of the deeply-seated part.

In the other case, under the law of reflex action the visceral nerves, and therefore the tissue-elements supplied by them, are soothed by the impression on the cutaneous nerves—while, especially when the

intervening structures are of no great thickness, the relaxing effects of the warmth and moisture are directly felt by the parts which are inflamed.

Some counter-irritants, as I need perhaps hardly remind you, have the effect also of abstracting blood from the vessels of the part. Cups, leeches, and scarifications are in various degrees useful in this way. It is obvious that the lessening of the amount of blood supplied to the excited tissues must deprive them of the excess of pabulum which they are attracting to themselves, and by cutting off their unduly abundant supplies must bring them into closer conformity with the standard of health. Here then is an actual loss from the sum total of the blood-mass, and therefore the benefit is permanent.

General bleeding, once so universally practised in the treatment of inflammation, acted in the same way. The blood-mass, being in relation with all the tissues, cannot be reduced in quantity without the effect being first felt at any point where it is in excess,—in congested or inflamed parts. It was however not only as the direct consequence of the taking away of so much blood, but also by the diminution of the heart's action from the less volume of the mass to be propelled, and from the sedation of the nervous system, which when in greater degree would constitute syncope, that the circulation within the affected part was lowered, and the excess of nutritive or formative irritation by so much reduced. Moreover, the same depression of the nervous system which would thus lower the action of the heart, would also diminish the innervation of the inflamed part, and thus by affecting

another of the conditions of nutrition would render it more nearly normal.

The whole class of derivatives, — diaphoretics, diuretics, purgatives, owe their value simply to the fact that they give another direction to the blood-current and to the nerve-force. They thus act upon three of the essential elements of nutrition, the quantity of the pabulum, its quality, and the innervation which we know is necessary to the process, and which is increased or deranged, or both, in inflammation. Often the relief given in these respects goes very far to put an end to the disease, since the tissue-elements themselves return to their normal state. Another source of the efficacy of such remedies is that they allay the constitutional fever, and as this, which at first is lighted up by the local disturbance, reacts upon and aggravates the latter, its subsidence removes one prop from the disease. In regard to all these processes, it seems to me that the modern doctrine before alluded to of the correlation of forces has a most important bearing. If the nerve-force be converted into the chemical, electrical, or vital force which is required for secretion, or under which that change of relation between the atoms, which constitutes secretion, takes place, then that nerve-force is no longer available as an element of formative irritation in the diseased part, or as an element of the systemic disturbance known as fever. If the blood is used for the purpose of secretion on the cutaneous surface, or on that of the urinary or alimentary mucous membrane, it cannot be also used by the irritated part in carrying on the morbidly increased and

deranged nutrition which enters so largely into the process of inflammation.

The influence of low diet in reducing inflammation is obviously analogous to that of the other depletory measures already spoken of. It not only deprives the irritated part of the pabulum for its excessive nutrition, but it cuts off a source of excitement from the nervous system, and thus diminishes innervation.

Anodynes, when applied directly to the tissue or organ which is the seat of the disease, act mainly upon the nerves distributed to it, and perhaps also upon the tissue-elements themselves. Their local employment is accordingly most beneficial when the part concerned is one of great sensitiveness, so that pain is a prominent symptom of the disorder. When they are so given as to be absorbed into the circulating blood, and to act on the central nervous system, they prevent in a measure that reflex action which was mentioned as an important element in the chain of morbid phenomena. And as you well know, when they are so used it is generally in combination with such remedies as promote secretion—so that we have not only the soothing effect belonging to them, but also the derivative effect upon the blood-mass and the nerve-force, which has been already discussed.

Astringents are very valuable as local applications in inflammation. They act not only upon the blood-vessels, shrinking them and causing a diminution in the quantity of blood which passes through the irritated part, but also upon the cells. Some of them, as for instance the acetate of lead, seem to

possess a certain degree of sedative power over the nerves, and perhaps over the tissue-elements also. I do not know that any satisfactory explanation of this power has ever been given, but the fact can hardly be questioned. Mechanical pressure, especially in parts endowed with no great sensibility, has much the same effect.

Certain articles in our materia medica have long been recognized as valuable local remedies in inflammation, without the mode of their action being clearly understood. Among these one of the most prominent is the nitrate of silver. This salt is a powerful astringent, and has also a marked effect in deadening the sensibility of parts to which it is applied. Tannic acid, and some of the salts of iron, have like properties. Iodine acts in the same way. It may be that the astringency of all these articles is the sole source of their efficacy, being exerted upon the nerve-filaments with which they come in contact. It certainly does not seem philosophical to ascribe to them any special and mysterious agency, without stronger proofs than have yet been adduced.

Astringents and anodynes may be combined with great advantage in the treatment of inflammations; as for instance, in cases of ophthalmia, where we have to deal with a superficial tissue, very vascular and very sensitive. Here we may employ the sulphate of zinc as an astringent, to cause shrinking of the blood-vessels, and we may add the sulphate of morphia as an anodyne, to allay pain.

There is one class of remedies for inflammation, whose efficiency has been long known, but whose exact mode of operation is still undiscovered. I

allude to what are called alteratives. Mercury in its various forms may be taken as the type of this class, which includes also iodine, arsenic, and apparently some of the salts of potassa. It is a singular circumstance that the salts of iodine and arsenic which have been most extensively and successfully employed as alteratives are those with potassa. The iodide of potassium, called by some chemists hydriodate of potassa, and the arsenite of potassa, are well-known agents of this class, and probably the soluble salts of this alkali, such as the nitrate, induce scurvy by an excess of like influence.

It is generally supposed that these substances enter into combination with the blood, and in some way influence its chemical composition, so as to render it less nutritive; according to the older investigators, they lessened its fibrine-forming power. But the subject is so far from being in any degree thoroughly understood, and indeed involves so many intricate questions in physiology, that time would fail me, even if I felt equal to the task of discussing it.

These articles differ somewhat in their methods of employment. Mercury and arsenic produce their effects most completely when they are insinuated, as it were, little by little, into the circulating blood. The former has a definite direction toward certain organs, of which the liver is the chief. Their soluble salts are powerfully irritant; arsenic itself is never given medicinally, while as you know mercury often is.

Iodide of potassium is capable of being taken into the stomach, and absorbed, in very much larger

quantity than either of the articles above mentioned. Its general distribution in this way is more effective than its local application—and its power is greatly increased, according to Parker and other writers on syphilis, by the addition to it of minute quantities of the more energetic salts of mercury.

As to the local employment of these remedies, they are of most value in discussing swellings, such as glandular enlargements, and the indurated masses of lymph which often remain after the inflammation has subsided which gave rise to them.

Now in all these cases, obscure as the precise mode of action of the remedies may be, the general fact is sufficiently obvious, that they exert an influence upon nutrition. Whether they act upon the blood alone, simply changing its composition, or have besides this an effect upon the tissue-elements, which seems very probable, they influence at least one of the factors in the nutritive process,—the quality of the nourishment supplied. If they act also upon the irritated cells, either, as may perhaps be not unlikely in the case of mercury at least, by a directly sedative impression, or by combining chemically with the cell-contents, it is easy to see how powerful their influence must be in modifying the nutrition of the part.

I do not know that there is any evidence to show that the alteratives, when locally applied, can influence either the quantity of the blood flowing through the vessels at the seat of disease, or the innervation of the affected tissues. But when they are used as general remedies, they may act in both these ways, since they would tend to excite secretion, and thus

not only to divert the current of the blood, but also to give a different direction to the nerve-force. And here it may be proper for me to remark somewhat more particularly upon this relation between secretion and inflammation. When, for example, the liver is inflamed, its secretion is checked; and it must be borne in mind that the secretion is thus checked because the hepatic tissue proper is engaged in responding to the stimulus, whatever that may be, which excited the inflammation. Now the administration of a mercurial, bringing on free secretion, unloads the vessels, as the phrase is; or in other words, it changes the character of the chemical processes which are taking place in the part, so that the liver cells perform their function, and use up the blood and the nerve-force which are in excess.

And from this illustration I may proceed to a suggestion, which I am not inclined to make too positive, but which will perhaps become established by further researches. Wherever the process of inflammation occurs, there is present either connective tissue or some representative of it. Connective tissue, as you know, is distributed everywhere through the body, so as to form a sort of soft skeleton, supplementary to the bony one. As Virchow aptly remarks, "we are almost warranted in regarding this tissue as a sort of neutral ground upon which other parts may meet,—a special arrangement for their intimate connection; an arrangement which, although it exercises no great influence upon the higher functions of the animal, is still of great importance in the matter of its nutrition."

The idea, then, which I would hint at, is that the

theatre of inflammation may perhaps be the connective tissue only; the special tissues being indeed involved, but in a secondary and merely incidental way. Upon this view it may easily be seen how the establishment of secretion should relieve inflammation—since even in the case of the liver the apparatus of secretion and that of nutrition, using the latter term in the strictest sense, would be separate. To state the case somewhat differently, the liver-cells are imbedded in connective tissue, within which ramify vessels and nerves; they are superadded to this scaffolding, as it were, upon which might have been just as well arranged an apparatus for the formation of saliva or urine. The liver-cells take what they want for their own nutrition and for the fulfilment of their function. When inflammation occurs, which we have regarded as a derangement of nutrition, the secretory process, which depends upon the secondary nutrition of the liver-cells, is interfered with. If re-established, it diverts the excess of nourishment and of nerve-force which was taken up in carrying on the inflammation, and thus relieves the disorder.

In the foregoing discussion, it has been my endeavor to adhere as closely as possible to a simple construction of the facts presented, without warping them for the support of any special views or theories. I think, however, that they bear out the statements previously advanced in regard to the process of inflammation. Those statements, you will remember, were that this process is always a disease, and that it always consists in a disorder of nutrition—that

the essence of this derangement is a change in the mutual relations of the blood and the tissues. It was also urged that this change depended, not upon an increased or diminished action, a contracted or relaxed state of the vessels, nor upon the mere augmentation of the quantity of blood furnished to the part—but that, as the tissue-elements themselves, according to the circumstances under which they were placed, demanded more or less blood, so their state was the immediate cause of all variations in this respect.

There is one point which remains to be noticed. I took the ground, not only that inflammation was always a disease, but that it was always essentially the same—any apparent differences between different cases depending upon incidental conditions. Thus the inflammation in a boil, that around a small-pox pustule, and that in a urethra affected with gonorrhœa, are according to this view of like character. And so also of that which occurs in diseases usually accepted as specific, such as syphilis or erysipelas. In any of these cases, so far as local treatment is concerned, it is now known that the simplest measures are the best. We may indeed seek to correct those properties of contagion which are in some way attached to the products of these diseases, or to counteract the constitutional states in which the local trouble either originates or finds a source of incessant renewal, but the inflammation itself is destitute of specific character, and is shown to be so by the simplicity of the remedies to which it yields.

It may be that such a statement will seem strange

to those who have been accustomed to employ, in syphilis or erysipelas for example, certain local dressings which have in their experience been found to answer well, and to which they have therefore been led to attach special virtues. But I do not know of any such articles, which can be proved to have a specific action. I believe they all depend upon the astringent, anodyne, and other powers, which have been already discussed as belonging to the means used in inflammations to which no specific character can in any way be ascribed. Nor do I think that it can be asserted that there is any one local treatment which will answer in every case of syphilis, of gonorrhœa, or of erysipelas.

You will perhaps remember, gentlemen, that in a former lecture I spoke of the disfavor into which many theories have fallen, which were not only proposed with confidence and defended with energy, but which were long accepted as settled principles in pathology. Such may possibly be the fate of the modern doctrines, rational and sound as we think them. But this, so far from discouraging scientific research, should stimulate it; leading us not to abandon the field, but to increase the honesty as well as the caution with which we work out and announce our results.

The views which it has been my duty and my pleasure to lay before you, are such as have seemed to me to be supported by facts; if their basis is sound and adequate, they will stand,—if otherwise, they must inevitably fall. And in so saying, I would not imply that they are not with me matters of

earnest conviction, or that they are put forth with indifference. They are offered as contributions to the modern system of pathology, with which I believe them to be in accordance. And with it, they must stand the test of time and further research; a test as severe as infallible.

THE END.